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By

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U. S. Geological Survey

Prepared in cooperation with the

Hamilton County Ground Water Conservation District
TED REGIER, *Chairman*

and

York County Ground Water Conservation District
DWIGHT WALKUP, *Chairman*

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USE OF GROUNDWATER FOR IRRIGATION IN HAMILTON AND YORK COUNTIES, NEBRASKA

By Eugene K. Steele, Jr.

ABSTRACT

About 317,000 acres, or 45 percent of the land in Hamilton and York Counties, Nebraska, is irrigated with water pumped from wells. Beginning in 1961, a downward trend of water levels in wells indicated that the groundwater supply was being depleted progressively in a large part of the two counties. Comparison of water levels in the spring of 1970 with estimated water levels prior to irrigation development indicates a net decrease of nearly 1 million acre-feet in the stored supply. Pumpage during the 1969 irrigation season, about 400,000 acre-feet, apparently did not contribute significantly to the long-term net decrease inasmuch as the weighted water-level change between the springs of 1969 and 1970 indicated almost no change in groundwater storage. If seasonal water-level declines are proportional to seasonal pumpage, hydrographs of water-level changes since 1958 in 10 wells indicate that 1969 pumpage was much less than pumpage in the years 1963-67, when the downward trend of water levels was the steepest.

INTRODUCTION

Hamilton and York Counties, in southeastern Nebraska (fig. 1), together constitute an area of 1,113 square miles, or 712,320 acres. Most of the two-county area is on an upland plain that slopes gently eastward and is drained by the Big Blue River and its tributaries. In a narrow band along the north boundary of Hamilton County, however, the land surface slopes steeply northwestward toward the Platte River, which forms the north county

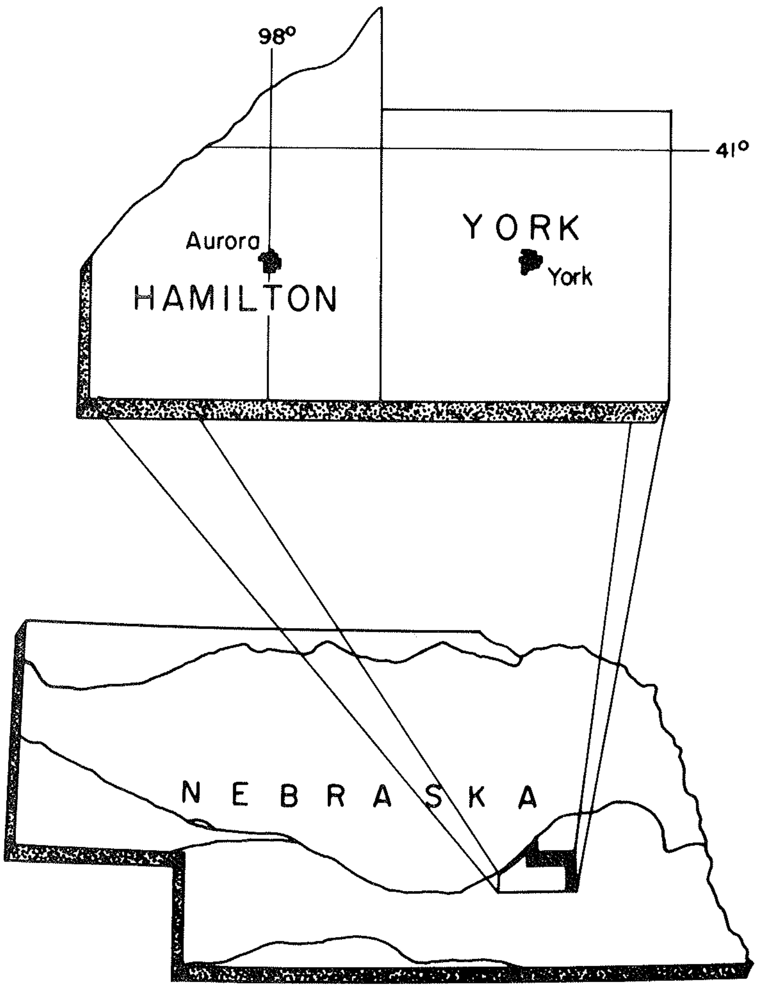


Figure I. – Index map showing location of Hamilton and York Counties.

boundary. Soils are mostly a silty loam and well suited for irrigation; only about 10 percent of the land in the two counties is too gullied, steeply sloping, or poorly drained to be irrigated.

The average annual precipitation ranges from about 25 inches in western Hamilton County to 28 inches in eastern York County; of this, nearly 75 percent falls during May to September. As growing-season precipitation generally is poorly distributed both areally and with respect to time, supplemental water is needed virtually every year to maximize crop yields.

At first, irrigation was restricted to lowlands along the Platte River, Big Blue River, Lincoln Creek, Beaver Creek, and West Fork Big Blue River, the supply of water being diverted by gravity or pumped from surface sources. As lowland areas are of only minor extent, the total cropland that can be thus irrigated never will be more than a small fraction of the total cropland in the two-county area. Lifting stream water to irrigate crops on the upland is not feasible because all the streams tend to have very low flows during prolonged dry weather, when the demand for irrigation water is the greatest.

Drilling of irrigation wells began during the drought of the 1930's, and by 1950 about 400 wells had been installed. The drought of 1955-56 resulted in greatly increased well-drilling activity; and by the end of 1969, the number of wells in Hamilton County had increased to 1,744 and in York County to 1,636 (State-Federal Division of Agricultural Statistics, 1970). The distribution of these wells is shown in figures 2 and 3. Annual well installations during 1945-69 and the cumulative number of wells by year during the same period are shown in figure 4 by bar graphs and line graphs, respectively. Comparison of the well-installation rate with graphs of yearly departures from both average growing-season and average annual precipitation at Aurora and York (fig. 5) shows the relation of well-drilling activity to precipitation.

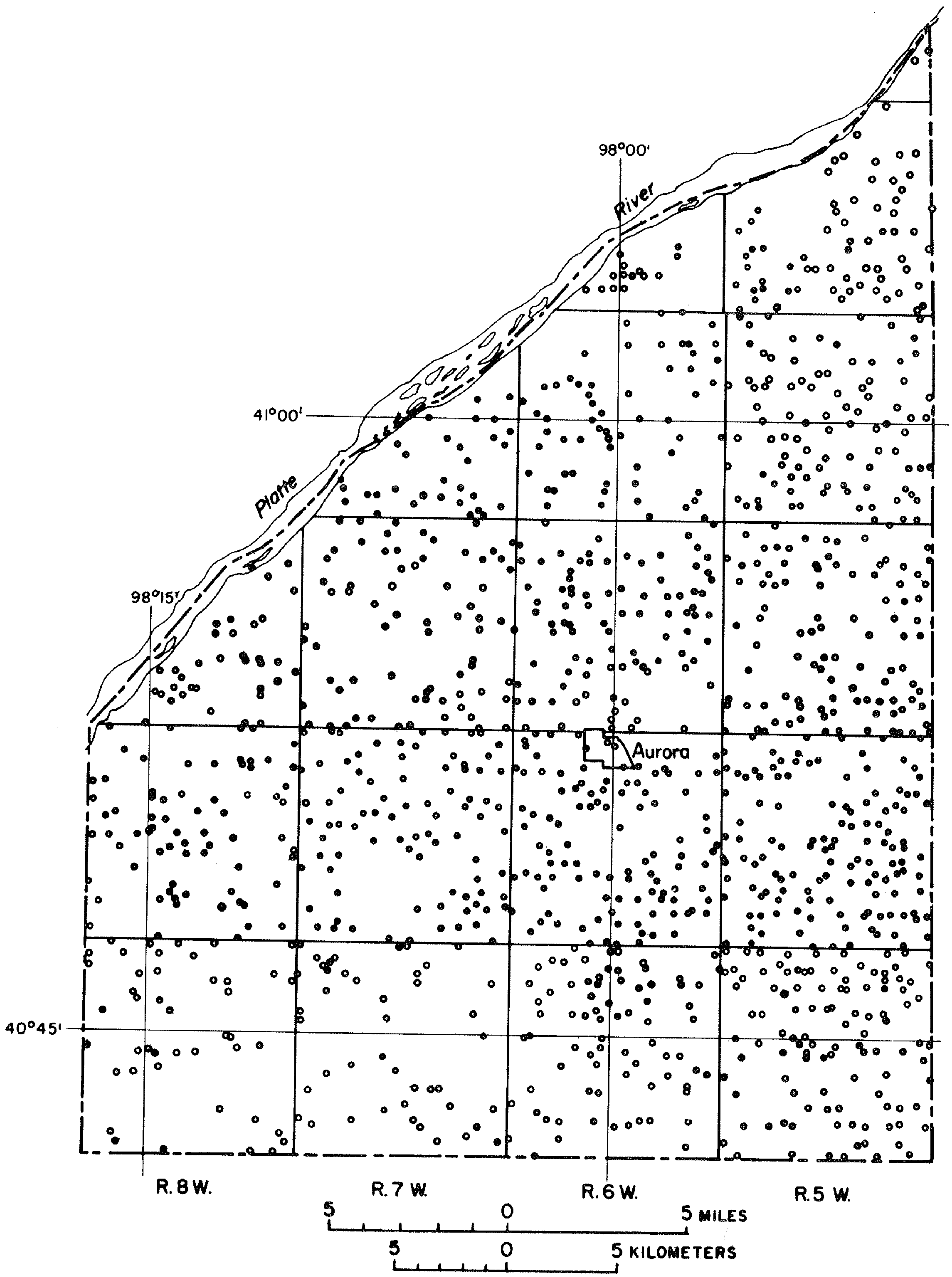


Figure 2.—Locations of irrigation wells in Hamilton County.

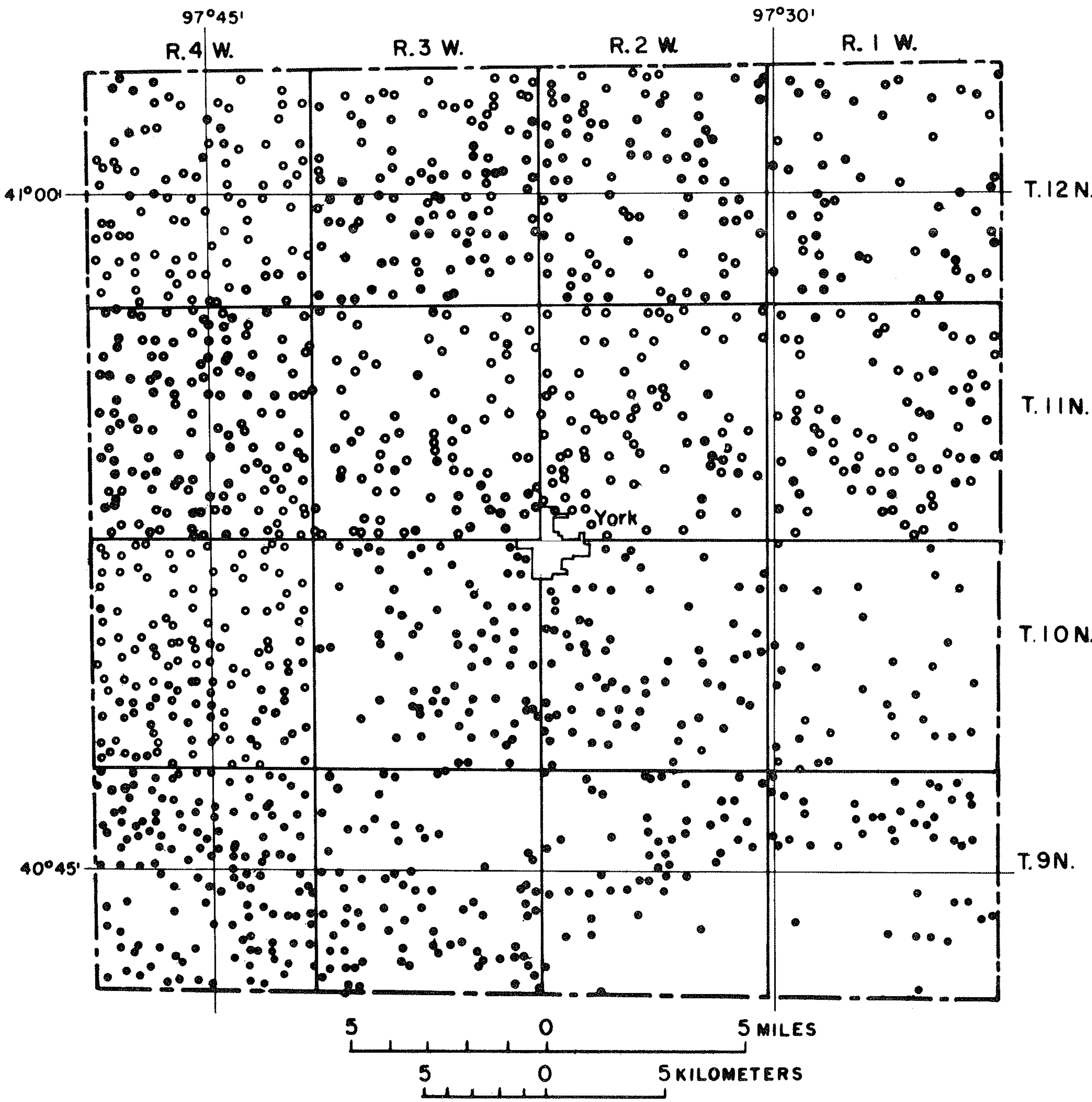


Figure 3.—Locations of irrigation wells in York County.

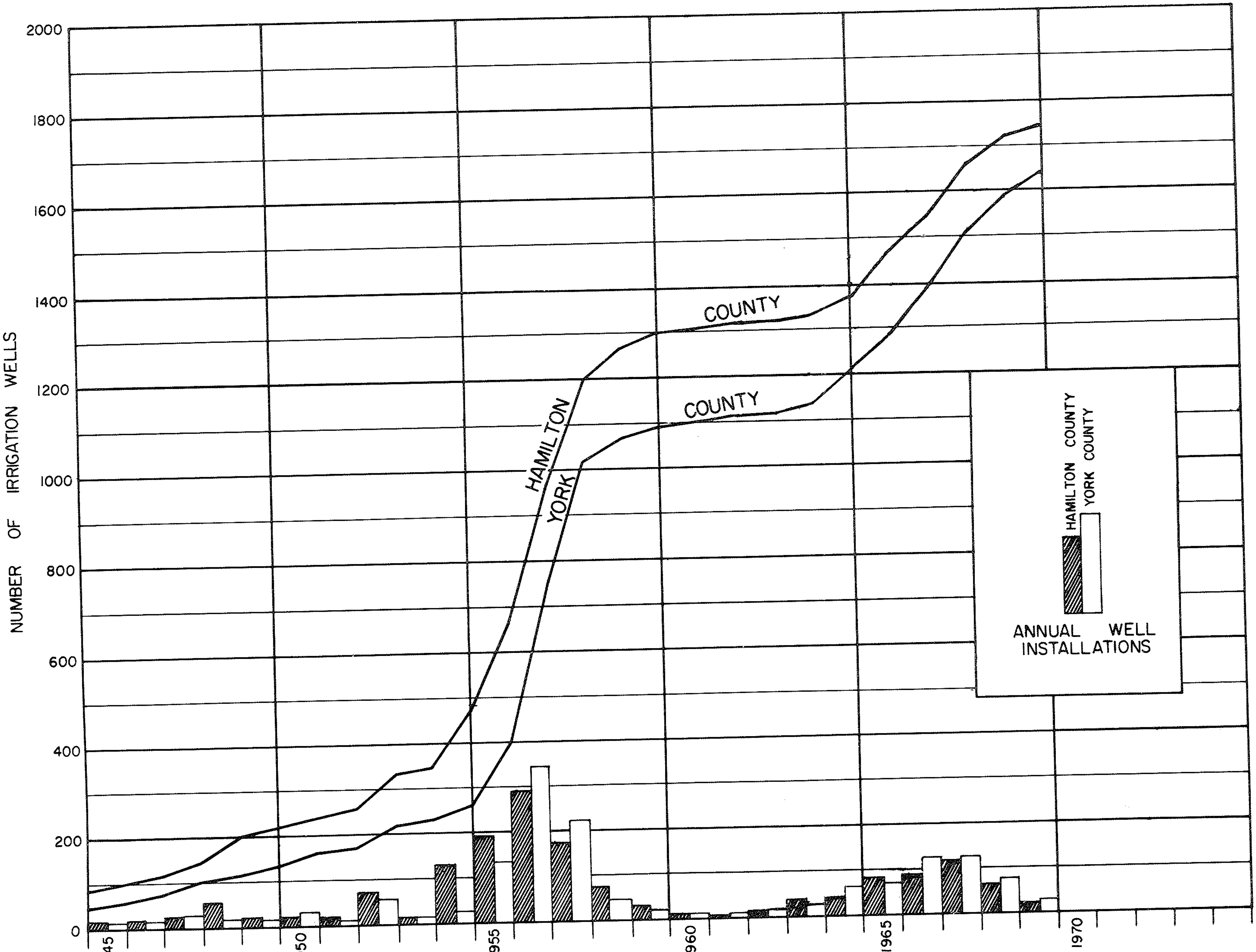


Figure 4. – Annual irrigation-well installations and cumulative total number of irrigation wells, 1945-69.

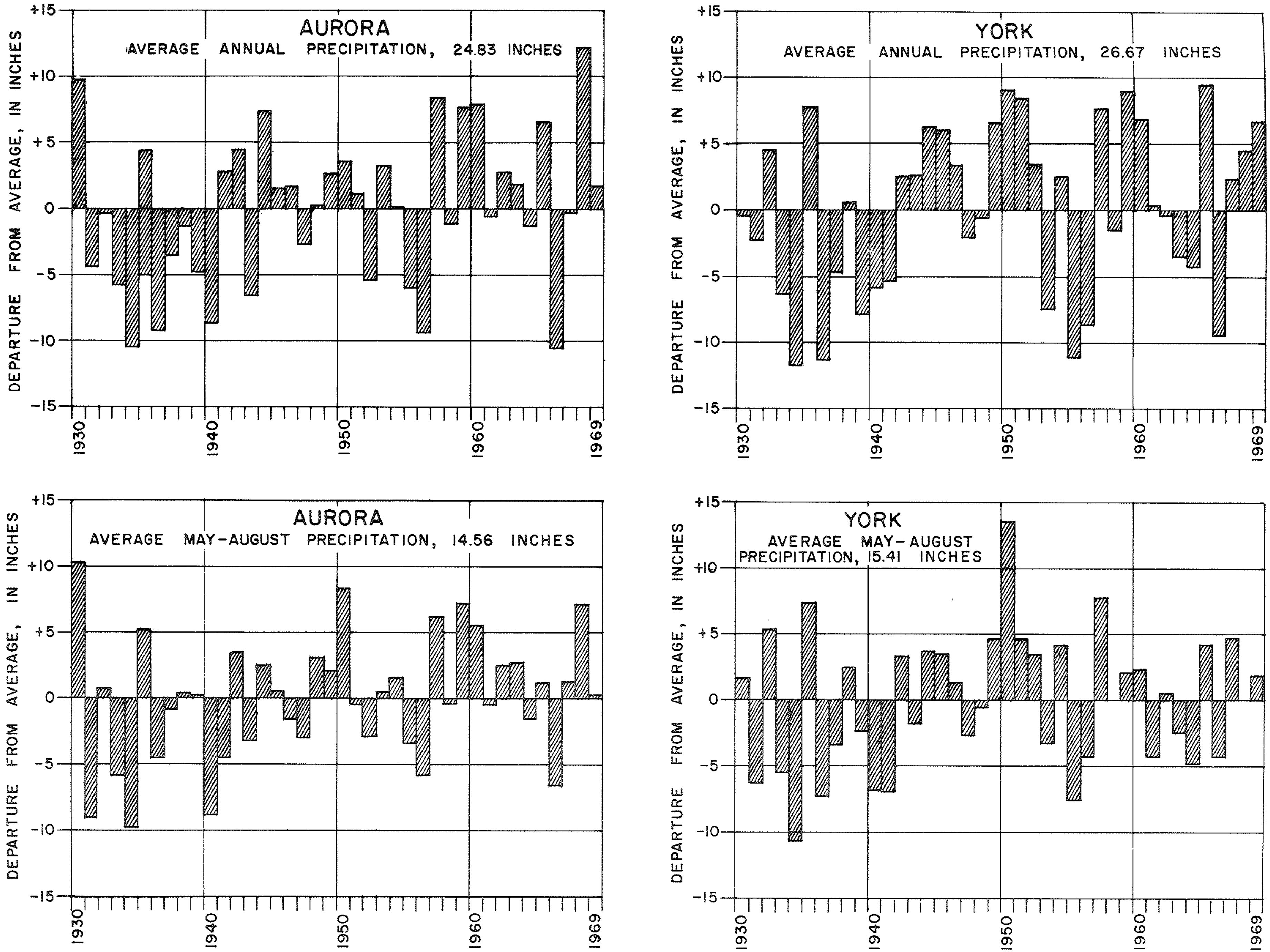


Figure 5.– Yearly departure from average growing-season and average annual precipitation at Aurora and York, 1930-69

Increase in the amount of water used for irrigation has been somewhat greater than the increase in number of wells. Formerly, farmers irrigated only when necessary to keep their crops from deteriorating, whereas most irrigators, to achieve maximum yields, now gear application of water to soil-moisture conditions and stage of crop growth. Rather than depending on summer rains for part of the moisture supply, many irrigators feel that summer rains merely complicate their operations. Furthermore, improvement and wider use of fertilizers and development of new crop varieties having greater potential yields have caused increases in the water requirements of crops, thus necessitating more frequent and heavier applications of irrigation water.

Corn is the principal irrigated crop in both counties; and, as irrigation is costly, high crop yields must be obtained to make it profitable. During 1954-69, the average yield of irrigated corn generally ranged from 1.6 to 2.9 times that of nonirrigated corn, but in the drought years 1955 and 1956 was, respectively, about 7 and 19 times greater. Although the maximum potential yield of corn has increased markedly, it is more nearly realized only when the crop is irrigated. Even in such years as 1962, 1966, 1968, and 1969, when climatic conditions were especially advantageous for dryland corn production, the average yield per acre of irrigated corn was 37 to 56 bushels, or 1.6 to 2.1 times, greater than that for nonirrigated corn.

Average yields for irrigated and nonirrigated corn, as compiled from annual reports of Nebraska agricultural statistics, are shown in the following table.

Table 1.--Average yields of irrigated and nonirrigated corn, 1954-69 [State-Federal Division of Agricultural Statistics, 1956-70]

Year	Bushels per acre			
	Hamilton County		York County	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated
1954	63	24	66	28
1955	63	8	64	9
1956	72	4	78	4
1957	74	38	74	37
1958	80	40	81	46
1959	79	48	83	48
1960	77	48	82	48
1961	80	33	80	29
1962	95	58	94	59
1963	85	36	92	38
1964	78	27	80	33
1965	105	45	107	43
1966	110	62	112	64
1967	109	45	106	58
1968	107	51	105	52
1969	119	70	122	77

Comparison of the yields of nonirrigated corn with the departures from average annual precipitation and average growing-season precipitation reveals that yields have little relation to precipitation amounts. Even though seasonal rainfall is considerably more than average, hot winds for a few days in succession or hot rainless periods 2-3 weeks long can be highly damaging to crops.

As of the end of 1969, about 49 percent (168,100 acres) of Hamilton County and 41 percent (149,500 acres) of York County was being irrigated with water from wells (State-Federal Division of Agricultural Statistics, 1970). Additional wells are likely to be installed in future years, and it is reasonable to assume that the irrigated acreage will continue to increase. Additional expansion of irrigation will depend upon the availability of water supply, the suitability of land, and other factors which include economic considerations. Although irrigation of the present magnitude eliminates much of the drought hazard for farmers, it places a heavy demand on the available groundwater supply. Even though the quantity of water still in storage is tremendous, continued heavy withdrawals are certain to result in a significant lowering of the water levels in wells, in interference between wells being pumped, in decreased yields from wells, and in abandonment of wells no longer capable of supplying enough water for irrigation use.

In a concerted effort to appraise and better manage the groundwater supply, a majority of the irrigators in both counties voted, in the middle 1960's, to organize the Hamilton County and the York County Ground Water Conservation Districts, as authorized by the 1959 Nebraska State Ground Water Conservation Act. In general, the Districts were formed to do the following (Axthelm and Hecht, 1967):

1. Work with and seek assistance from all local, state, and federal agencies having expertise in appraisal, development, and protection of groundwater resources.
2. Develop a program for eliminating waste of water.
3. Investigate methods and encourage research on more effective use of rainfall.
4. Investigate and develop potential groundwater and surface-water resources for recharge and irrigation.
5. Determine costs of water for various crops and pumping conditions.
6. Begin a program of water-level measurement throughout the District and coordinate the program with those of state and federal agencies.

7. Investigate the possibility of income-tax benefits in compensation for depletion of groundwater reserves.

8. Provide a pumping-plant testing program.

9. Institute measures, if and when necessary, to correct wasteful practices relating to groundwater use.

10. Perform, as the need arises, additional functions related to groundwater conservation.

In 1969, both Districts contracted with the U.S. Geological Survey to evaluate their groundwater resource, to determine the effect of groundwater pumpage upon the available supply, and to obtain data needed by the Districts to manage their water resources. This report, which presents the results of the study through the spring of 1970, is a step towards obtaining facts needed for a detailed appraisal of adequacy and longevity of the water supply. Considerable additional data will be needed before projects that would supply supplemental water can be undertaken.

Pertinent information from earlier publications that describe the geology and water resources of Hamilton and York Counties has been used in making this appraisal. Those publications are included among the selected references listed at the end of this report.

ACKNOWLEDGMENTS

Many persons aided in this study by contributing time and information. H. H. Hecht and J. C. Cranfill, County extension agents, provided information on well locations and records of depth to water in wells. In addition to providing financial support, the District Boards of the Hamilton and York County Ground Water Conservation Districts publicized the study locally and encouraged pump operators to cooperate by keeping records of hours pumped and

permitting water-level and water-yield measurements to be made. District Chairmen Ted Regier and Dwight Walkup provided information and data obtained by their Districts prior to the study and rendered valuable assistance while the study was in progress.

WELL-NUMBERING SYSTEM

Wells are numbered in this report according to their location within the system of land subdivision of the U.S. Bureau of Land Management. The numeral preceding the N (north) indicates the township, the numeral preceding the W (west) indicates the range, and the numeral preceding the terminal letters indicates the section in which the well is located. The terminal letters A, B, C, and D indicate location within the section; the first letter denotes the quarter section, or 160-acre tract, and the second the quarter-quarter, or 40-acre tract. The letters are assigned in a counterclockwise direction, beginning in the northeast corner of each tract. The well-numbering system is illustrated in figure 6.

METHODS USED AND SUMMARY OF DATA COLLECTED

The principal goal of the investigation during 1969 was to devise a method whereby annual pumpage for irrigation, beginning in 1969, could be related to annual changes in water levels and the corresponding changes in groundwater storage. Because obtaining records of pumpage and water-level changes for so many irrigation wells was not feasible, such information was obtained for a representative sample of wells so that average values for the sample in each county then could be applied to the entire county. A total of 119 wells--51 in Hamilton County and 68 in York County--were selected for the

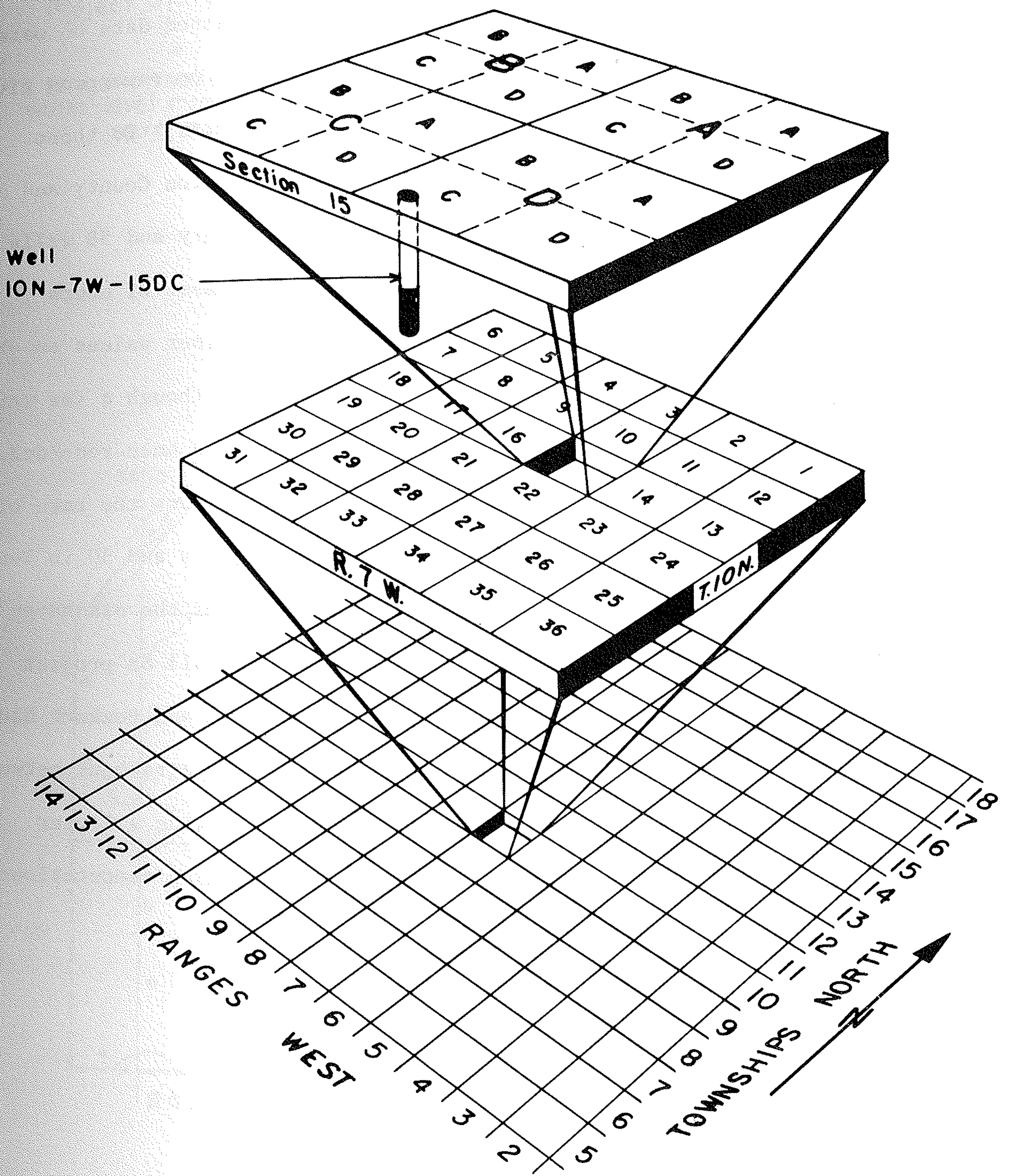


Figure 6. — Well-numbering system.

sample and are referred to in this report as project wells. (See figs. 7 and 8.) Those in Hamilton County were selected from wells for which a water-level record several years long was available, and those in York County were the same as ones for which Axthelm and Bozkurt (1969) had obtained data on water levels, yields, and hours of operation. Each project-well operator was given a calendar on which he was asked to record hours of operation. Of those given out, 48 calendars were returned by operators in Hamilton County and 55 by operators in York County. For 22 wells in Hamilton County and 38 wells in York, fuel-consumption records were used to compute the number of hours pumped. Most such computations were made to determine whether values so obtained correlate closely with reported hours of operation, though a few were made to obtain a value for hours of operation where none had been recorded.

Either a current meter or a Pitot tube was used to measure the rate of discharge from 70 of the project wells--40 in Hamilton County and 30 in York County. Those made in York County served as a spot check of the discharge measurements made in 1968 by Axthelm and Bozkurt (1969) on all 68 project wells in that county. Considered necessary because Axthelm and Bozkurt had used a different type rating device, the check showed close agreement between the earlier and later measurements. Therefore, as they provide a larger sample, the earlier discharge measurements were used in making computations of pumpage for York County.

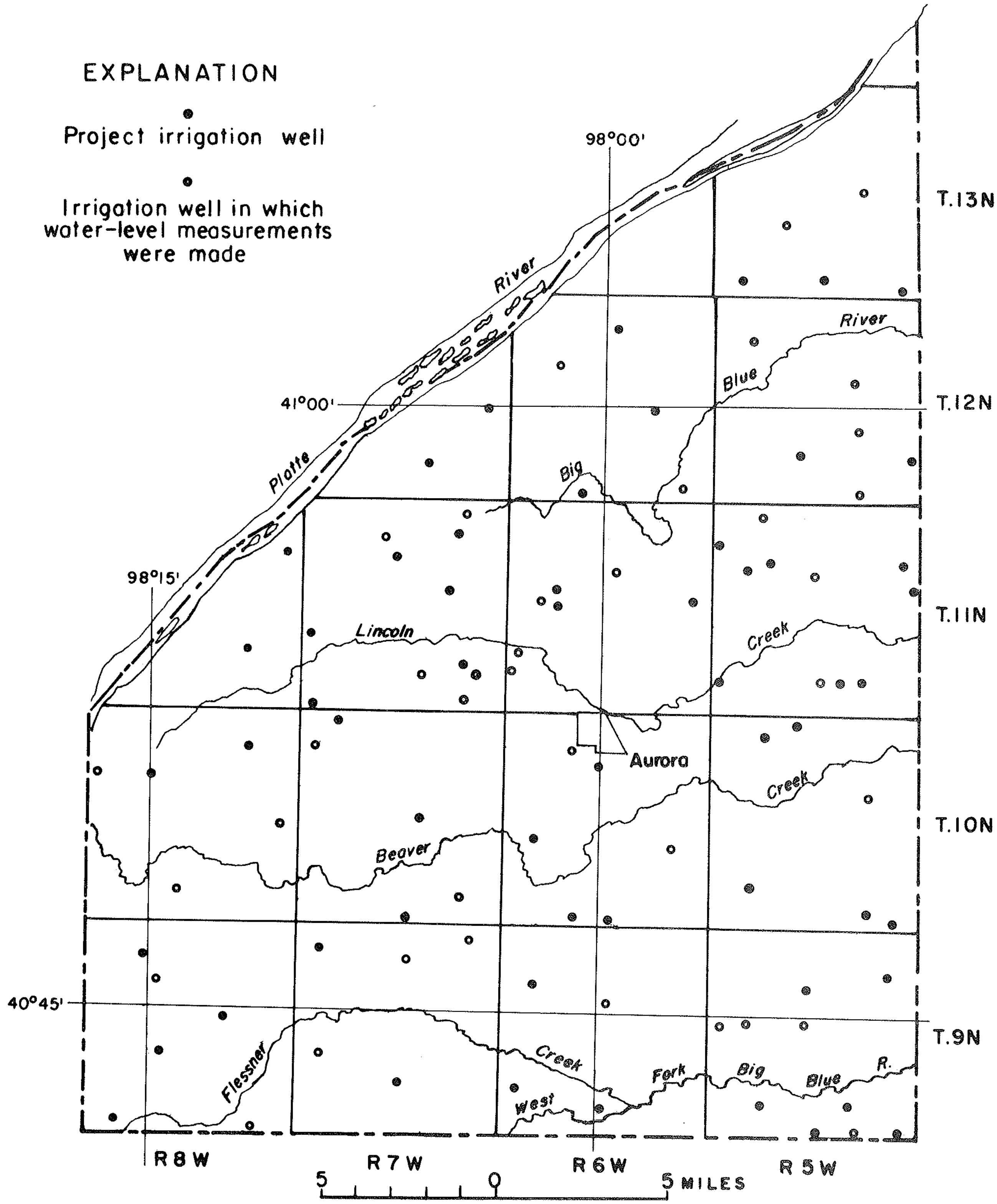


Figure 7.— Locations of project wells and selected other irrigation wells in Hamilton County.

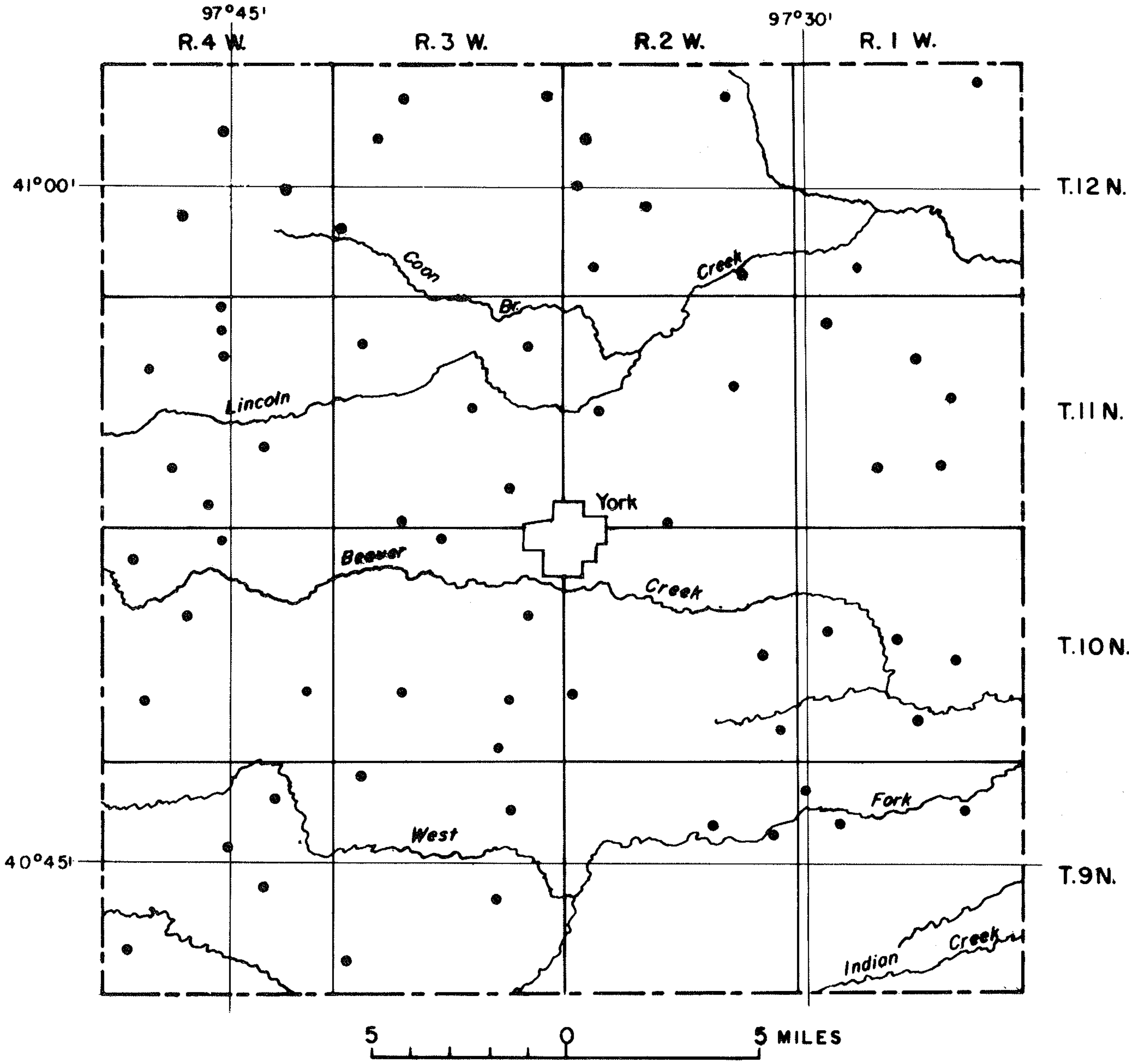


Figure 8.—Locations of project wells in York County.

A predevelopment water level was estimated for each project well (tables 3 and 4, p.20 and 22, respectively) so that water-level and water-storage changes since irrigation began could be computed. In making these estimates, use was made of water-level measurements and water-table contour maps in earlier reports.[1/] As part of the fieldwork for this report, measurements of the depth to water in all project wells were made in the spring and fall of 1969 and again in the spring of 1970. As most of these same wells had also been measured in the fall of 1968--in Hamilton County by the Hamilton County Ground Water Conservation District and in York County by Axthelm and Bozkurt (1969)--water-level and water-storage changes could be computed for several different periods.

Other data collected consisted of drawdown, type of power, time pumped during the 1969 irrigation season, and number of acres irrigated. The following table summarizes the collected information, which is presented in detail in tables 3 and 4 for Hamilton and York Counties, respectively.

[1/] Average water levels in the 1948-51 period were assumed to represent predevelopment conditions. Water levels had recovered by then from the effects of drought in the 1930's and had not yet been affected significantly by withdrawals for irrigation.

Table 2.--Summary of data for project wells in Hamilton and York Counties
[All averages are arithmetic (nonweighted)]

	Hamilton County	York County
Number of wells	51	68
Depth to water, prior to irrigation development:		
Maximum....feet..	106.00	120.00
Minimum....do....	22.00	12.00
Average....do....	81.00	76.00
Depth to water, spring 1969:		
Maximum....feet..	115.68	121.83
Minimum....do....	22.43	12.64
Average....do....	89.25	80.76
Depth to water, fall 1969:		
Maximum....feet..	118.54	122.52
Minimum....do....	23.27	14.52
Average....do....	90.73	82.30
Depth to water, spring 1970:		
Maximum....feet..	116.16	121.35
Minimum....do....	22.68	14.47
Average....do....	89.10	80.95
Water-level difference, spring 1969 to spring 1970:		
Maximum rise....feet..	2.85	.83
Maximum decline....do....	.84	2.53
Average....do....	+.15	-.19
Wells for which discharge was rated	40	(1/)
Rate of discharge:		
Maximum....gallons per minute..	1,930	2/1,881
Minimum....do....	300	2/392
Average....do....	837	2/838
Wells for which time pumped was recorded by operator	48	3/55
Time pumped:		
Maximum....hours..	1,139	1,209
Minimum....do....	292	113
Average....do....	679	658
Total....do....	33,279	40,814
Pumpage:		
Maximum....acre-feet..	248	252
Minimum....do....	23	13
Average....do....	108	102
Area irrigated:		
Maximum....acres..	250	140
Minimum....do....	35	21
Average....do....	97	76
Total....do....	4,769	4,585
Depth of water applied to crop:		
Maximum....feet..	2.59	3.18
Minimum....do....	.23	.24
Average....do....	1.18	1.30
Wells having pumps run by natural gas	36	34
Wells for which gas consumption records were obtained	25	27
Wells having pumps run by electricity	3	11

Table 2.--Summary of data for project wells in Hamilton and York Counties--Continued

	Hamilton County	York County
Wells for which electricity consumption records were obtained	0	11
Wells having pumps run by propane, tractor fuel, or diesel fuel	11	23

1/Yield of all project wells was rated by Axthelm and Bozkurt (1969) in spring of 1969; yield of 30 of those wells rerated during this investigation.
2/Based on ratings by Axthelm and Bozkurt (1969).
3/One operator reported 0 hours of pumping.

As the project wells are not spaced on a regular grid, average net water-level change for various periods are most nearly accurate if computed by weighting the water-level change in each well according to the size of the area represented by the well. The Thiessen method used to weight water-level changes areally was as follows: 1. The locations of all project wells were plotted on a map of the two-county area. 2. A polygon was constructed around each well location so that all points within the polygon were closer to that well site than to any other. 3. The area of each polygon was determined by planimeter. 4. The water-level change in each well was multiplied by the appropriate polygon area. 5. The resulting products for each county were summed and divided by the county area to obtain an areally weighted water-level change for the county. All computations were made by digital computer. Now that the polygon map has been prepared, polygon areas determined, and a program written to perform all the mathematical operations, weighted-average net water-level change for the period between any two sets of water-level measurements can be determined with a minimum effort.

To determine the change in storage corresponding to the weighted average net water-level changes for a given period, the water-level change was

Table 3.--Records of project and selected other irrigation wells in Hamilton County, Nebraska

Well number: See text for explanation of well-numbering system. Type of power: D, diesel; E, electric; NG, natural gas; P, propane, TF, tractor fuel.

Well number	Operator	Water level (feet below measuring point)				Water-level difference, Spring 1969 to Spring 1970 (feet)	Draw-down (feet)	Type of power	Rate of discharge (gpm)	Hours of operation in 1969		Acres irrigated in 1969
		Predevelopment (estimated)	Spring 1969	Fall 1969	Spring 1970					Computed	Recorded	
9N-5W- 9DB	Albert Thieszen	82.00	91.55	92.73	90.29	+1.26	......	NG	....	....	325	100
9N-5W-12BB	B. M. and H. M. Friesen	79.00	88.40	88.99	87.14	+1.26	......	P	....	....	512	120
9N-5W-16CD	Harlan Nickolaus	97.00	103.96	104.90	103.22	+.74	......	TF	....	....	....	....
9N-5W-17CB	Ed Peters	79.00	85.66	86.44	84.53	+1.13	......	P	....	....	....	....
9N-5W-18CA	Robert Friesen	84.00	90.66	91.64	89.94	+.72	......	TF	....	....	....	....
9N-5W-26CC	Gideon Redler	27.00	28.35	28.89	28.41	-.06	......	P	....	....	878	80
9N-5W-29DC	Marvin Peters	28.00	28.31	28.96	28.68	-.37	......	P	....	....	1,014	113
9N-5W-34CC	Leo S. Ochsner	86.00	90.14	89.86	89.17	+.97	33	TF	610	....	292	50
9N-5W-35CD	Curtis Griess	83.00	87.60	87.74	86.17	+1.43	......	P	....	....	....	....
9N-5W-36DC	Harold and Gilbert Hofman	90.00	94.66	95.76	93.14	+1.52	16	NG	710	606	474	112
9N-6W- 7DA	Harold Nunnenkamp	69.00	76.62	77.19	76.10	+.52	......	P	....	....	....	....
9N-6W-15BB	Willard Epp	78.00	85.14	85.62	84.13	+1.01	......	P	....	....	....	....
9N-6W-30BC	R. O. Ueckert	70.00	76.66	76.29	75.98	+.68	......	P	....	....	....	....
9N-6W-34BA	Earl Bell	22.00	22.43	23.27	22.68	-.25	11	P	760	....	648	54
9N-7W- 3CD	Bob Hawthorne	76.00	84.36	84.89	83.90	+.46	......	P	....	....	....	....
9N-7W- 6DA	Carl Schrock	70.00	77.92	78.46	77.37	+.55	......	NG	....	....	....	....
9N-7W-19DA	Ronald Coats	78.00	85.76	85.87	85.29	+.47	......	.....	....	....	....	....
9N-7W-27BC	Kreutz Brothers	81.00	89.73	90.40	88.48	+1.25	16	NG	1,210	....	678	95
9N-8W- 5DC	Robert Zersen	80.00	86.07	87.27	84.77	+1.30	43	NG	1,140	728	766	190
9N-8W- 9CB	E. P. Leinert	73.00	79.16	80.57	78.10	+1.06	......	P	....	....	....	....
9N-8W-14CD	Harold Schultz	71.00	78.37	78.68	77.79	+.58	......	TF	....	....	....	....
9N-8W-21CB	Leonard Consbruck	57.00	60.31	63.01	57.46	+2.85	34	NG	300	685	617	75
9N-8W-31DA	Ira Rhodes	59.00	60.22	59.14	58.35	+1.87	36	NG	310	....	662	91
9N-8W-35DD	Arthur Kline	84.00	86.70	87.56	84.10	+2.60	......	P	....	....	....	....
10N-5W- 4BA	William Peetzke	80.00	94.07	95.41	93.87	+.20	9	NG	760	867	....	....
10N-5W- 5BD	Frank Friesen	82.00	93.95	95.97	94.27	-.32	17	NG	1,020	....	970	136
10N-5W-14AB	Richard Regier	83.00	95.83	98.63	96.09	-.26	......	NG	....	....	....	....
10N-5W-29CB	I. H. Goertzen	78.00	88.88	90.16	88.10	+.78	......	NG	....	....	....	....
10N-5W-35DA	Aldon Thieszen	76.00	88.04	89.20	87.22	+.82	10	NG	700	....	882	90
10N-5W-36CC	Albert Friesen	77.00	89.55	90.44	88.67	+.88	20	NG	1,230	826	852	80
10N-6W- 9DB	Robert Kremer	77.00	88.04	89.54	87.95	+.09	14	NG	860	505	478	158
10N-6W-19AA	Dick Williams	80.00	87.44	88.20	87.19	+.25	......	NG	....	....	....	....
10N-6W-33CB	Ed. R. Warren	82.00	92.01	92.69	91.48	+.53	......	NG	....	....	466	90
10N-6W-34CC	Roger Epp	91.00	98.49	99.95	97.68	+.81	11	E	730	....	672	90
10N-7W- 5BB	Vernon Salmon	86.00	94.28	96.29	93.99	+.29	......	.....	....	....	....	....
10N-7W- 6DC	Harold Beins	95.00	102.42	104.72	102.56	-.06	......	E	....	....	....	....
10N-7W-15DC	Louis Oswald	76.00	84.28	84.68	84.00	+.28	......	NG	....	....	359	122
10N-7W-34CC	Bob Hawthorne	74.00	83.67	84.50	83.12	+.55	13	NG	820	673	813	85
10N-7W-35AA	C. A. Huenefeld	80.00	89.80	90.24	89.37	+.43	......	.....	....	....	....	....
10N-8W- 2DC2	Paul R. Weber	93.00	99.57	101.08	99.06	+.51	......	NG	....	....	793	70

10N-8W- 7CB	Reed Hongsermeier	66.00	68.83	70.25	68.67	+.16	26	NG	1,930	591	515	170
10N-8W- 8DD	George Falmlen	76.00	80.91	82.60	80.23	+.68	14	NG	940	....	852	75
10N-8W-24AB	Eldon Bish	83.00	89.13	89.85	88.34	+.79	......	.....	....	....	....	....
10N-8W-33AB	R. H. Kreutz	86.00	91.92	94.17	90.74	+1.18	......	.....	....	....	....	....
11N-5W- 5BA	A. Anderson	86.00	99.75	102.17	100.20	-.45	......	.....	....	....	....	....
11N-5W- 6CC	Arlie Smith	90.00	104.18	107.08	104.77	-.59	22	NG	940	....	1,053	140
11N-5W- 8CA	Alfred Alberts	103.00	115.04	117.97	115.52	-.48	......	P	....	....	....	....
11N-5W- 8CB	Larry Fagan	104.00	115.68	118.54	116.16	-.48	18	NG	450	791	760	72
11N-5W- 9DB	R. C. Joseph	80.00	93.66	95.62	94.34	-.68	......	P	....	....	....	....
11N-5W-12DB	LaVern Klute	78.00	92.01	94.64	92.42	-.41	20	NG	630	427	421	35
11N-5W-13AB	Raymond Parpart	74.00	87.86	89.29	88.36	-.50	19	NG	1,160	1,165	777	146
11N-5W-26CC1	Herbert Klute	82.00	94.63	97.44	95.04	-.41	24	NG	780	991	1,139	75
11N-5W-27CC	A. L. Peterson	77.00	89.69	91.62	90.07	-.38	......	NG	....	....	....	....
11N-5W-27DD2	G. W. Klute	82.00	92.43	93.52	92.27	+.16	16	NG	710	....	789	77
11N-5W-30CC	Rodney Enderle	32.00	42.20	43.14	43.04	-.84	16	P	1,260	....	550	53
11N-6W-10CC	Dick Grosshans	75.00	85.49	87.24	86.43	-.94	......	NG	....	....	....	....
11N-6W-13CB2	John Ediger	91.00	103.02	106.83	103.77	-.75	20	NG	1,020	829	849	60
11N-6W-17BD	Maynard Jensen	90.00	98.95	101.16	99.71	-.76	27	NG	1,010	954	968	110
11N-6W-17CD	.....do	94.00	105.79	106.93	105.35	+.44	25	NG	630	964	1,063	90
11N-6W-30BA	.....do	41.00	48.99	50.87	49.71	-.72	......	D	....	....	....	....
11N-6W-30CB	Don Beins	81.00	93.27	94.98	93.54	-.27	......	P	....	....	....	....
11N-7W- 2AA	Howard Purdy	81.00	88.99	90.59	89.06	-.07	......	NG	....	....	....	....
11N-7W- 2DC	Elton Elge	92.00	99.46	100.59	100.24	-.78	13	NG	900	415	348	70
11N-7W- 9AD	Robert Bartlett	91.00	97.71	99.89	97.66	+.05	22	NG	800	727	758	125
11N-7W-14CA	John Olson	93.00	108.03	109.79	108.75	-.72	11	NG	360	....	708	108
11N-7W-19BB	Alvin Purdy	89.00	94.63	97.98	95.14	-.51	33	NG	900	....	628	98
11N-7W-25CC	Maylon Hanson	80.00	88.58	90.45	88.97	-.39	......	NG	....	....	....	....
11N-7W-26AC	.....do	90.00	92.42	94.40	92.98	-.56	......	NG	....	....	....	80
11N-7W-31CD	Gene Heuermann	94.00	102.69	104.14	102.28	+.41	......	NG	1,370	312	318	86
11N-7W-35AC	Helmer Wadell	77.00	87.94	89.75	88.20	-.26	......	P	....	....	....	....
11N-8W-12AC	Gene Gustafson	84.00	84.53	84.73	84.26	+.27	19	NG	890	975	1,079	90
11N-8W-26AC	Harold Stuhr	90.00	92.97	96.01	93.34	-.37	21	NG	520	418	456	55
12N-5W- 8BB	Alvin Rohn	76.00	80.54	81.84	80.46	+.08	......	P	....	....	....	....
12N-5W-14BC	Art Dose	80.00	94.07	95.72	94.21	-.14	......	.....	....	....	....	....
12N-5W-25AD	Harvey Wochner	101.00	114.64	116.70	114.84	-.20	......	E	....	....	....	....
12N-5W-28AC	Donald Beyer	89.00	101.74	103.19	102.19	-.45	......	E	....	....	702	70
12N-5W-35CB	Paul Budnick	84.00	97.57	99.49	97.70	-.13	......	D	....	....	....	....
12N-6W- 3CC	Warren Nilson	105.00	109.98	110.99	110.52	-.54	18	P	510	....	576	95
12N-6W- 8DC	Edwin Empken	112.00	115.72	116.29	115.44	+.28	......	.....	....	....	....	....
12N-6W-23BA	Francis Forsberg	80.00	88.85	91.17	89.23	-.38	34	P	360	....	348	100
12N-6W-33CA	Roland Christenson	100.00	109.21	111.25	109.75	-.54	28	NG	750	748	896	101
12N-6W-36BC	Chester Beyer	90.00	103.62	105.52	104.45	-.83	......	P	....	....	....	....
12N-7W-24BA	Victor Jerloff	104.00	110.78	111.74	110.54	+.24	8	NG	990	617	306	125
12N-7W-27DC	Clarence Sands	106.00	113.34	114.44	113.48	-.14	16	P	930	....	436	85
13N-5W-14CD	Irvin Larsen	106.00	114.14	112.93	111.53	-.39	......	.....	....	....	....	....
13N-5W-21CC	Darold Ortegren	99.00	105.70	107.04	105.92	-.22	......	.....	....	....	....	....
13N-5W-31AD	Francis Irwin	100.00	102.89	104.19	103.12	-.23	37	P	790	....	682	45
13N-5W-34BC	Kenneth Clayton	86.00	96.20	97.84	96.30	-.10	18	P	790	....	510	82
13N-5W-36DC	Harold Anderson	82.00	93.66	95.11	93.83	-.17	......	.....	....	....	774	250

Table 4.--Records of project irrigation wells in York County, Nebraska

Well number: See text for explanation of well-numbering system. Type of power: D, diesel; E, electric; NG, natural gas; P, propane.

Well number	Operator	Water level (feet below measuring point) Predevelopment (estimated)	Spring 1969	Fall 1969	Spring 1970	Water-level difference, Spring 1969 to Spring 1970 (feet)	Draw-down (feet)	Type of power	Rate of discharge (gpm) 1968	1969	Hours of operation in 1969 Computed	Recorded	Acres irrigated in 1969
9N-1W- 6CC	Carl Smith............	32.00	32.36	33.59	33.47	-1.11	16	E	501	.....	510	....	60
9N-1W- 8CB	Elmer Kruse...........	23.00	22.52	24.02	24.39	-1.87	7	E	1,141	.....	526	343	120
9N-1W-11BA	Clarence Hoffschneider.	24.00	25.89	27.70	27.19	-1.30	22	E	842	.....	481	587	90
9N-2W-10DA	Claude Bailey..........	21.00	21.07	23.23	23.60	-2.53	11	E	451	440	784	678	30
9N-2W-12CD	Carl Smith............	19.00	19.88	21.59	21.58	-1.70	20	E	807	820	545	....	50
9N-3W- 5DB	Abraham Buller.........	79.00	85.48	86.27	84.99	+.49	15	P	1,054	940	....	424	52
9N-3W- 5DC	.....do...............	77.00	79.89	80.63	79.44	+.45	10	D	907	.....	....	224	70
9N-3W- 6AC	Logen Otto............	81.00	84.35	85.52	83.79	+.56	14	P	1,881	.....	....	0	0
9N-3W-11AB	Alvin Critel...........	82.00	83.79	84.79	84.44	-.65	30	P	842	860	....	756	100
9N-3W-23CB	Jake Friesen...........	77.00	80.77	80.89	80.29	+.48	25	P	1,097	1,080	....	737	80
9N-3W-31BA	William Kleinholz......	92.00	95.86	97.13	95.03	+.83	20	E	908	890	966	986	80
9N-4W- 2DC	S. R. Janzen...........	80.00	85.44	87.49	85.59	-.15	13	P	995	1,250	....	649	58
9N-4W- 5BB	Gus Friesen............	85.00	89.47	90.72	88.94	+.53	8	E	652	.....	542	658	37
9N-4W-15BB	August Franz...........	80.00	89.77	91.54	89.62	+.15	25	E	821	970	791	....	......
9N-4W-23BB	Epp Brothers...........	81.00	88.10	89.77	87.67	+.43	11	P	882	680	....	548	80
9N-4W-30DC	John Kliewer...........	86.00	87.47	88.46	87.20	+.27	14	NG	1,005	.....	....	530	83
10N-1W-16DC	Ewald Morner...........	76.00	79.72	80.23	80.00	-.28	18	P	967	.....	....	603	80
10N-1W-18DA	Robert Klone...........	101.00	104.84	105.06	104.62	+.22	10	NG	603	.....	....	502	60
10N-1W-23BC	Clarence Pieper........	90.00	91.87	92.54	92.09	-.22	17	P	1,005	1,080	....	586	82
10N-1W-27CC	Clarence Hofman........	51.00	51.44	51.90	51.95	-.51	22	D	603	610	....	....	30
10N-2W-24BB	Leo Geis..............	103.00	106.90	107.63	106.87	+.03	29	NG	678	880	453	514	65
10N-2W-30BB	James Dickey...........	83.00	86.83	87.45	86.22	+.61	29	D	832	830	....	404	60
10N-2W-36AA	Lloyd Naber............	120.00	121.83	122.52	121.35	+.58	18	NG	1,113	.....	423	....	......
10N-3W- 4AA	Dave Kirkpatrick.......	60.00	65.24	66.21	65.69	-.45	21	NG	880	.....	164	....	......
10N-3W-13BB	Donald Swan............	82.00	87.47	88.04	86.98	+.49	20	NG	778	.....	948	972	100
10N-3W-26AC	Roscoe Stevens.........	87.00	93.46	94.20	92.67	+.79	21	NG	893	.....	521	542	75
10N-3W-29AA	Keith Ellis............	79.00	84.54	84.95	84.53	+.01	18	P	400	850	....	173	55
10N-3W-35CB	Lloyd Wolstenholm......	78.00	82.62	83.13	82.07	+.55	18	P	488	.....	....	246	21
10N-4W- 3BB	Henry Ediger...........	60.00	66.75	68.82	67.24	-.49	19	NG	631	.....	775	778	46
10N-4W- 6DA	Virgil Thieszen........	80.00	88.04	89.29	88.07	-.03	37	NG	683	.....	1,214	1,209	75
10N-4W-16BB	Albert Franz...........	77.00	83.69	86.95	83.65	+.04	24	NG	1,377	1,360	979	982	115
10N-4W-25BA	Arlin Siebert..........	76.00	81.90	83.34	81.12	+.78	35	NG	773	710	876	866	70
10N-4W-29BC	Homer Doell............	87.00	93.35	95.75	92.91	+.44	21	NG	887	900	695	800	70
11N-1W- 6DA	Mark Romohr............	89.00	91.68	93.26	92.26	-.58	14	NG	511	.....	762	797	70
11N-1W-10BC	Lynn Westwood..........	103.00	105.26	106.53	105.33	-.07	12	NG	842	840	809	900	140

11N-1W-14CB	Ralph Naber...........	98.00	100.40	101.64	100.44	-.04	16	P	941	800	....	729	112
11N-1W-27AD	R. P. Naber...........	108.00	111.69	112.82	111.62	+.07	17	E	1,070	.....	445	....	83
11N-1W-28BC	Ralph Eggerling........	100.00	104.14	104.95	103.82	+.32	21	D	1,084	1,080	....	553	95
11N-2W-14BD	Virgil Thorne..........	89.00	92.27	93.36	92.13	+.14	23	P	669	470	....	....	......
11N-2W-18BB	William Tietmeyer......	61.00	63.47	64.74	63.72	-.25	29	NG	838	.....	298	327	30
11N-2W-33DC	John Stahr.............	84.00	89.14	89.92	88.93	+.21	12	E	626	.....	415	578	51
11N-3W- 7AA	Erwin Hankel...........	61.00	65.53	71.07	67.33	-1.80	27	P	1,160	1,220	....	707	83
11N-3W-12BB	Chester Plock..........	60.00	64.02	66.47	64.82	-.80	34	NG	1,468	.....	329	274	80
11N-3W-15DC	Kenneth Barr...........	81.00	91.11	92.01	91.03	+.08	15	E	392	.....	365	....	......
11N-3W-26CD	Consolidated Blenders..	80.00	85.43	87.02	85.57	-.14	16	NG	603	.....	113	....	60
11N-3W-32DD	Melvin Kreifels........	65.00	68.73	69.78	69.02	-.29	30	NG	469	460	923	955	56
11N-4W- 3BB	Roger Kaiser...........	88.00	90.57	93.91	91.04	-.47	21	NG	1,138	1,140	561	490	55
11N-4W- 3CC	Frank Kirkpatrick......	85.00	86.58	89.80	87.32	-.74	14	NG	607	600	648	746	70
11N-4W- 8CC	Howard Warner..........	72.00	79.18	81.23	79.94	-.76	16	NG	1,243	.....	537	570	80
11N-4W-10CB	Lloyd McLain...........	84.00	91.97	94.38	91.97	.00	15	NG	821	.....	984	1,075	70
11N-4W-23DC	Donald Wahl............	72.00	81.33	82.68	81.79	-.46	17	NG	802	.....	784	998	78
11N-4W-29AD	Earl Foster............	71.00	80.59	81.93	81.04	-.45	13	NG	826	.....	1,111	1,006	55
11N-4W-33AD	Douglas Driewer........	73.00	83.46	85.43	83.40	+.06	12	NG	678	720	1,137	1,148	96
12N-1W- 2AD	Melvin Dey.............	98.00	98.28	99.51	98.11	+.17	21	P	617	.....	....	650	60
12N-1W-32AB	Donald Gruber..........	82.00	88.64	91.22	89.53	-.89	8	NG	764	.....	583	430	97
12N-2W- 2CC	Dale Moore.............	73.00	80.78	82.24	81.26	-.48	20	P	1,029	.....	....	674	80
12N-2W- 7DB	Donald Lytle...........	73.00	80.04	82.07	79.73	+.31	14	NG	921	.....	794	897	77
12N-2W-19BA	Glenn Phillips.........	67.00	74.61	76.74	74.76	-.15	22	NG	883	.....	....	797	130
12N-2W-21CB	Melvin Gruber..........	68.00	71.93	74.02	72.34	-.41	21	P	877	.....	....	....	110
12N-2W-31AA	Lawrence Youngland.....	68.00	74.81	76.73	74.94	-.13	15	NG	912	.....	....	540	63
12N-2W-35DC	Ralph Ellison..........	12.00	12.64	14.52	14.47	-1.83	17	P	854	.....	....	....	......
12N-3W- 1DB	James McLean...........	90.00	96.82	99.60	96.85	-.03	22	NG	867	.....	....	839	140
12N-3W- 5DD	Winton Wright..........	91.00	99.47	100.86	99.90	-.43	37	P	415	390	....	1,158	90
12N-3W- 8CD	J. D. Hirshfield.......	90.00	100.19	101.66	100.53	-.34	27	NG	483	430	....	1,311	75
12N-3W-30BA	Leonard Hoffman........	68.00	74.51	77.16	74.29	+.22	24	NG	962	.....	762	867	85
12N-4W-10CB	Fred Bedient...........	73.00	87.08	88.82	87.30	-.22	21	NG	886	.....	884	893	115
12N-4W-21CC	Edward Recknor.........	80.00	95.27	97.28	95.29	-.02	26	P	537	500	....	....	......
12N-4W-23AA	James Monier...........	77.00	87.19	89.65	87.22	-.03	34	NG	816	810	....	343	35

multiplied by the county area and multiplied by 0.20, which is considered to be a reasonable value for the specific yield[1/] of the water-bearing sandy gravel that underlies Hamilton and York Counties. As the change in water level is expressed in feet and the county area in acres, the change in storage is in acre-feet.

Two methods were used to determine total pumpage in 1969. The first consisted of the following steps:

1. Number of hours each project well was pumped was multiplied by that well's rate of discharge. (Computed hours of operation were used only if recorded hours were not known; 1968 rate of discharge was used for all wells in York County.)
2. The resulting product was converted to acre-feet.
3. Pumpages of individual project wells in each county were averaged.
4. Average for project wells in each county was multiplied by total number of wells in that county.

The second method was as follows:

1 and 2. Same as in first method.

3. Pumpage in acre-feet for each project well was divided by number of acres irrigated to determine depth of water applied.
4. Depths of water applied (acre-feet per acre) from project wells in each county were averaged.
5. The average value for water applied from project wells in each county was multiplied by the total number of acres irrigated in that county.

Again the digital computer was used for all computations.

[1/] Specific yield is the ratio of (1) the volume of water that a water-saturated material will yield by gravity drainage to (2) the volume of that material.

CHANGES IN WATER LEVEL AND GROUNDWATER STORAGE

Before water was pumped for irrigation in Hamilton and York Counties, the quantity of groundwater and the position of the water table beneath these counties remained nearly constant as compared to changes occurring since irrigation development. Additions (recharge) to the supply resulting from precipitation that infiltrated to the water table and from subsurface inflow beneath the west boundary of Hamilton County were balanced, over the long term, by losses (discharge) resulting from evapotranspiration, seepage into surface drainageways, and subsurface outflow into Polk and Seward Counties. Because the rates of additions and losses varied independently, the quantity of water in storage changed continually in response to the ever-changing ratio of one to the other. However, storage changes in one direction never persisted for long, and no upward or downward trend characterized fluctuations of the water table. Now that so much water is being pumped from irrigation wells, recharge and discharge are no longer in balance, and because discharge exceeds recharge, both the quantity of groundwater and water levels in wells are trending downward, as shown by the hydrographs in figures 9, 10, and 11.

The water-level measurements, which provided data for plotting the hydrographs, generally were made twice a year--once in the spring before pumping for irrigation began and once in the fall after pumping ended. As may be seen, the annual water-level declines between spring and fall measurements differ considerably in magnitude, and the amount of water-level recovery between fall and spring measurements ranges from a very small fraction of the preceding seasonal decline to as much or more than that decline. It is because the sum of the annual declines is more than the sum of the annual recoveries that the long-term water-level trend is downward. If

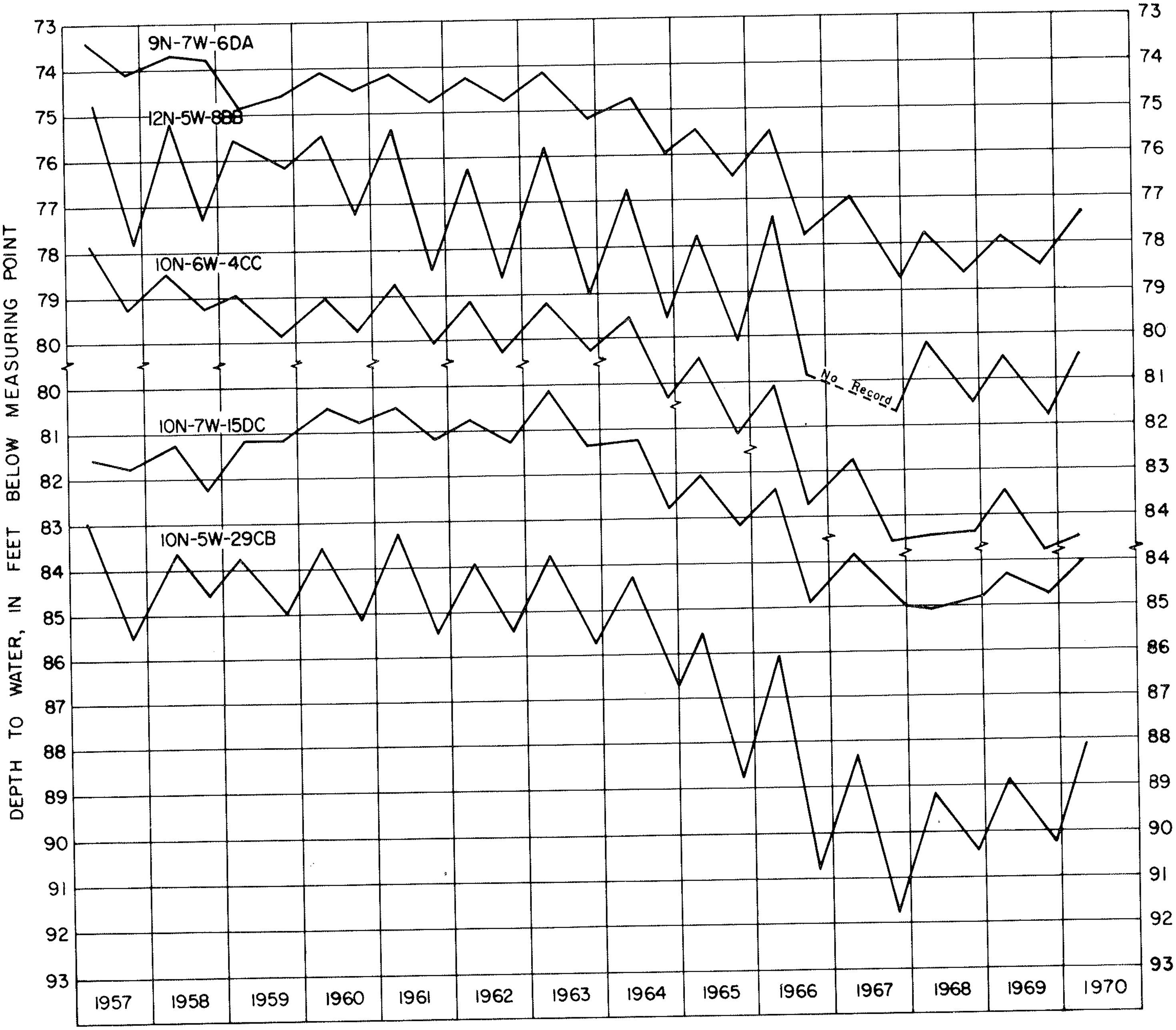


Figure 9.— Hydrographs for five wells in Hamilton County, 1957–70.

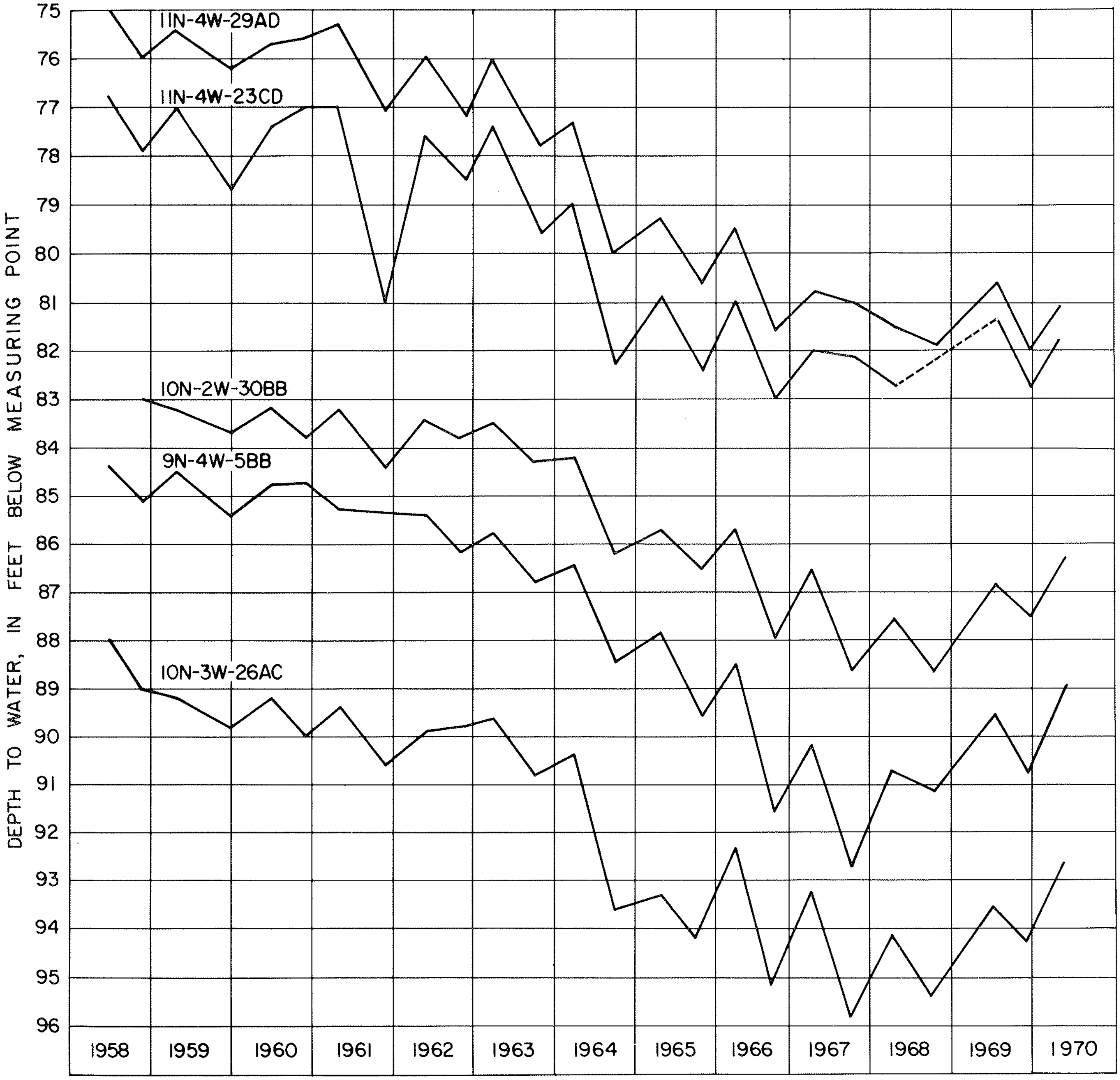


Figure 10.— Hydrographs for five wells in York County, 1958–70.

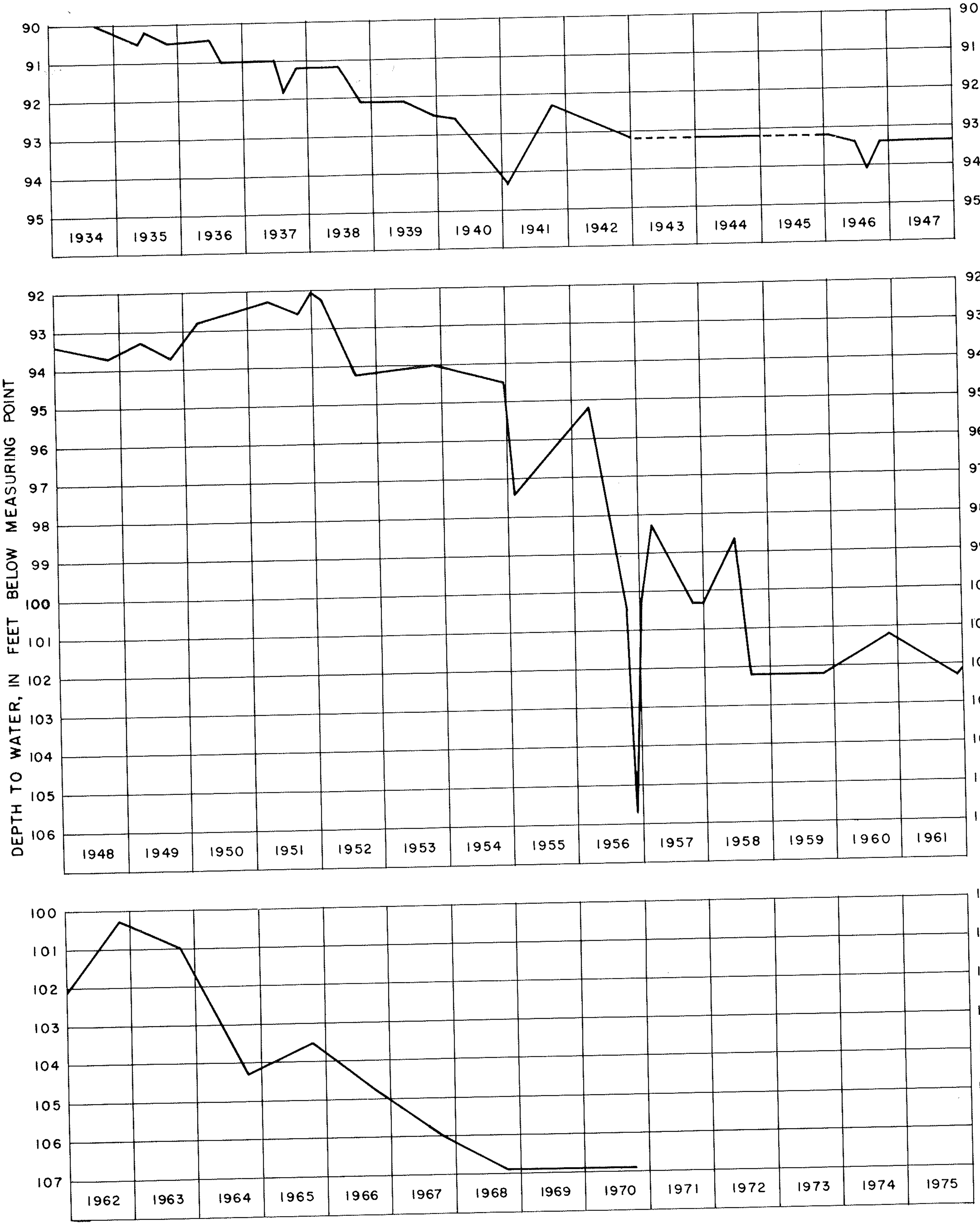


Figure 11.— Hydrograph of well 11N-6W-13CB in Hamilton County, 1934-70.

water-level measurements had been made more frequently during the nonpumping season and hydrographs plotted from them, the differences between the seasonal high and low water-level positions probably would be greater in most years than that shown by the hydrographs in figures 9, 10, and 11. Even so, the long-term trend would be similar. Of special interest to this study is the fact that the spring 1970 water-level measurements, as shown by the hydrographs for wells 9N-7W-6DA and 10N-5W-29CB in Hamilton County and for wells 9N-4W-5BB, 10N-2W-30BB, and 10N-3W-26AC in York County, indicate higher water levels than those for spring 1967. In fact, the downward trend that characterized the preceding 5 or 6 years is shown to have been either arrested or reversed in the 1967-70 period. However, a long-term downward trend of water levels has been established and will undoubtedly continue. The rate of decline in the future will depend upon climatic conditions, amount of groundwater withdrawn, and irrigation and water conservation practices.

The amount of water-level decline that has occurred in the two-county area since irrigation began is not everywhere the same. As shown by figure 12, the area in which the decline was greatest (10 to 15 feet) is centered in east-central Hamilton County but extends also into York County. Furthermore, the area characterized by a small decline (less than 5 feet) is somewhat larger in York than in Hamilton County. Comparison of the predevelopment water levels with those of spring 1970 indicates a weighted average water-level decline of 7.9 feet in Hamilton County and 5.7 feet in York County and reductions of storage amounting to about 545,000 and 420,000 acre-feet, respectively. A similar comparison of predevelopment water levels with those of spring 1968 indicates that in both counties the reduction of storage during that period was somewhat greater--585,000 acre-feet in

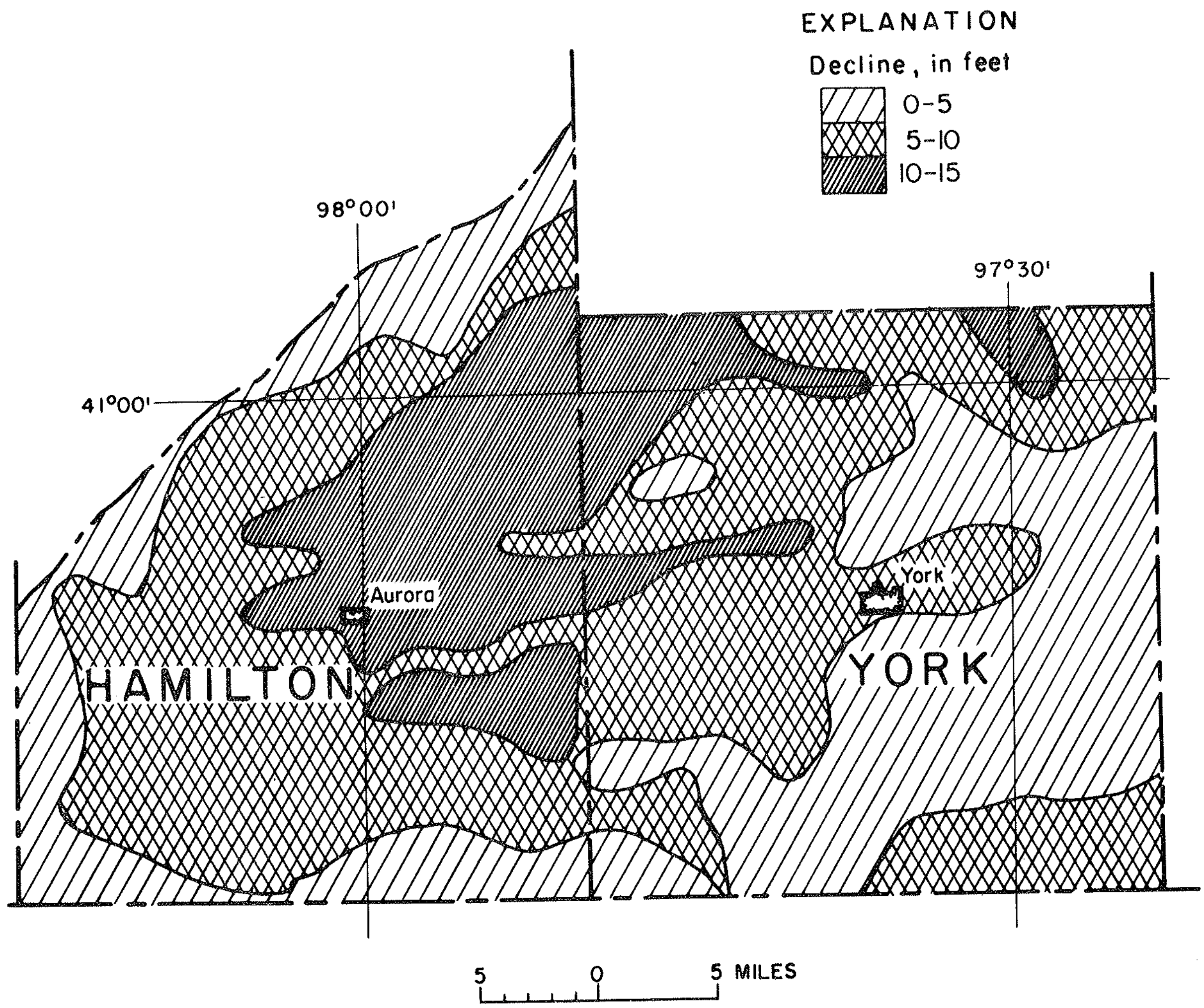


Figure 12.– Difference between estimated predevelopment water levels and spring 1970 water levels

Hamilton and 430,000 acre-feet in York--than during the predevelopment to spring 1970 period, a net gain in storage having occurred between spring 1968 and spring 1970.

In neither county was the net storage gain in the 2-year period accompanied by a water-level rise in all project wells. Instead, most of the wells in which rises occurred are within the lined area shown in figure 13A and most of those in which declines occurred are within the dotted areas. In Hamilton County the weighted net change in water levels during the 2-year period was +0.48 foot and in York County was +0.18 foot.

The distribution of net rises and declines in the two 1-year periods spring 1968 to spring 1969 and spring 1969 to spring 1970 are shown by figures 13B and 13C, respectively. In Hamilton County, the weighted average water-level change was a positive value in both years (+0.33 foot the first year and +0.15 foot the second) but in York County was a positive value in only the first year (+0.30 foot) and a minus value (-0.12 foot) the second.

Comparison of the spring 1969 and fall 1969 water levels in project wells (fig. 14) indicates that the greatest general lowering of water levels occurred in east-central Hamilton County and northwestern York County. Because precipitation during the 1969 growing season was less in that part of the two-county area than elsewhere (figs. 15 and 16), it would seem that Axthelm and Bozkurt (1969) were correct in their conclusion that the amount of groundwater withdrawn for irrigation use is related inversely to the amount of precipitation during the growing season. However, some evidence indicates that distribution of precipitation with respect to time during the growing season may be an even more important factor. For example, most of the hydrographs in figures 9 and 10 indicate that seasonal declines (here assumed to be roughly proportional to seasonal withdrawals) were nearly as

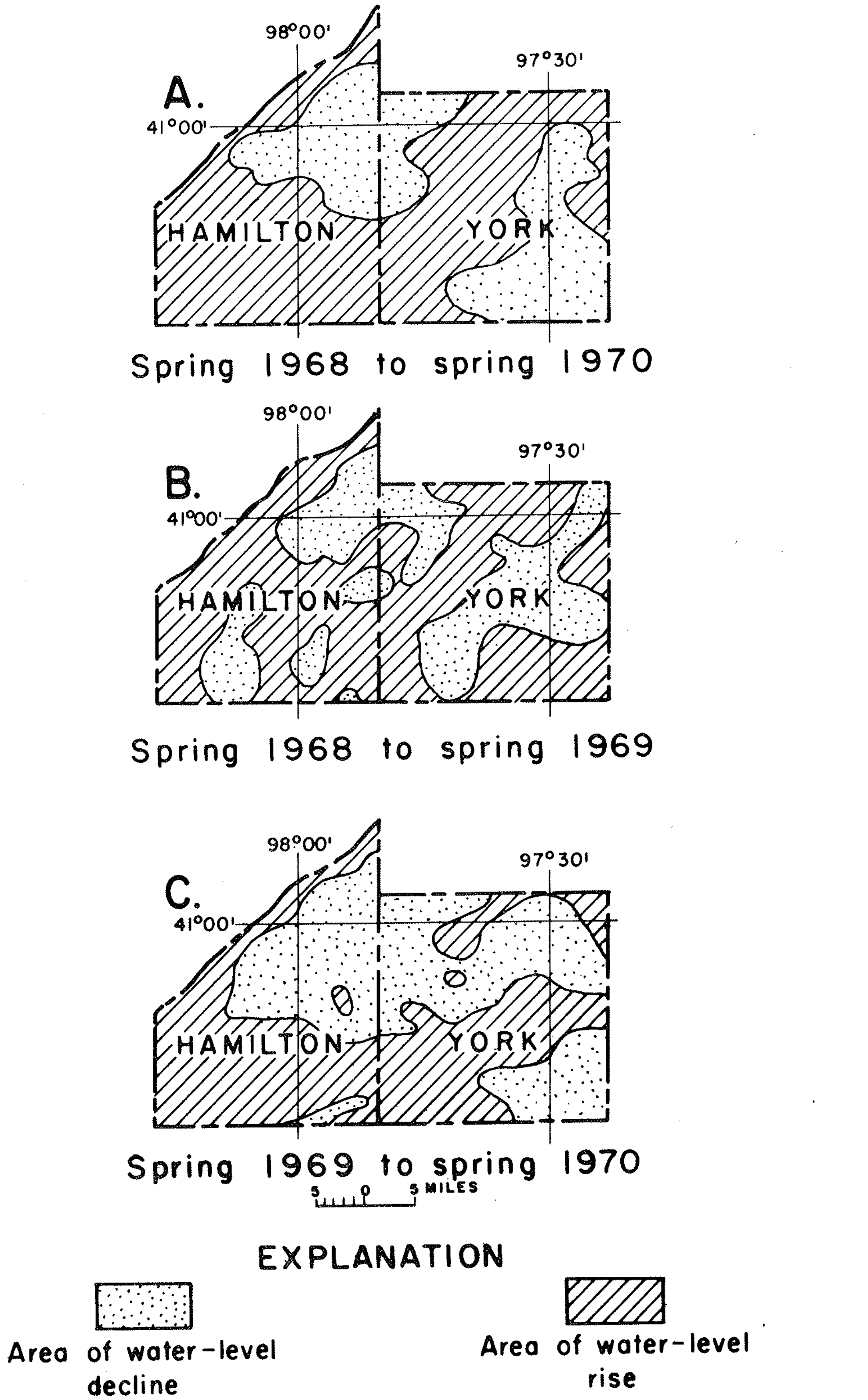


Figure 13.—Water-level declines and rises between (A) spring 1968 and spring 1970, (B) spring 1968 and spring 1969, and (C) spring 1969 and spring 1970.

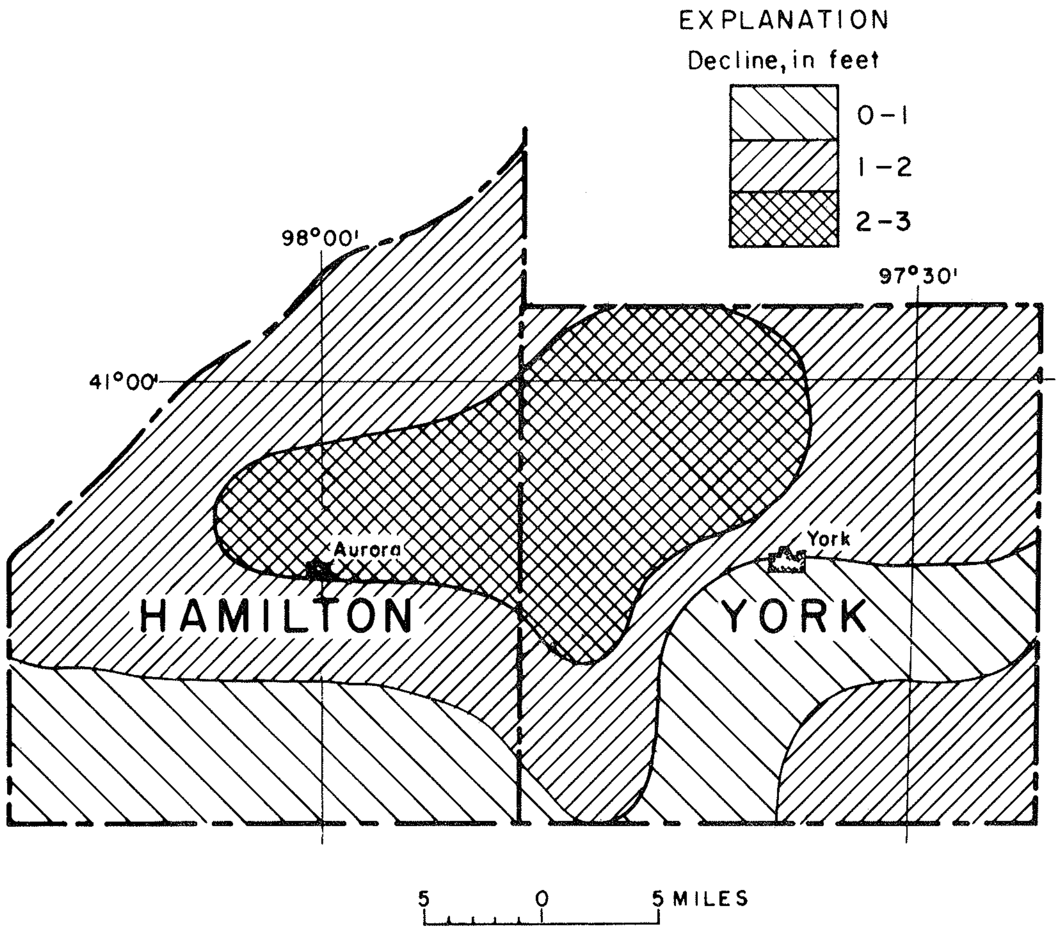
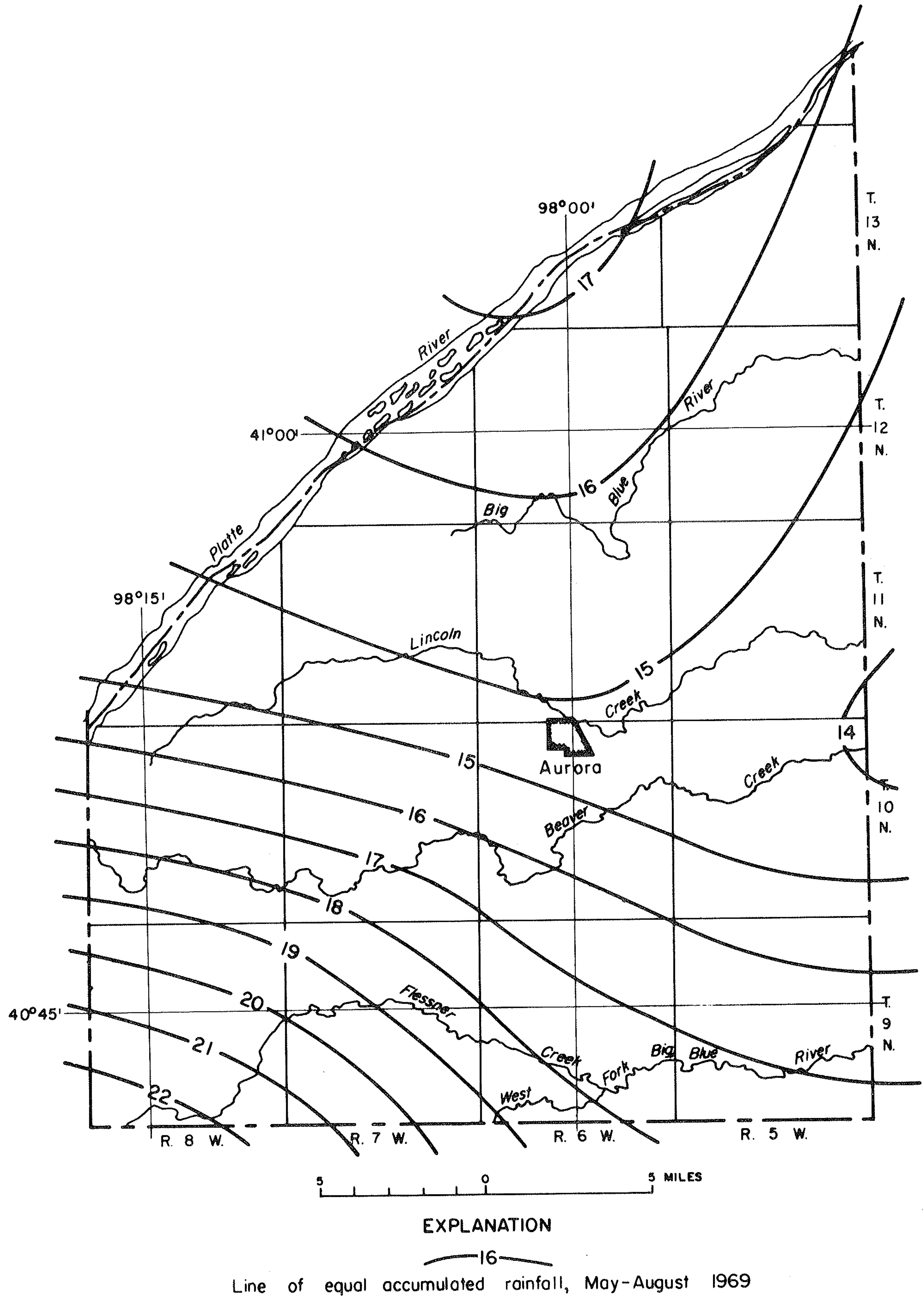


Figure 14.–Difference between spring 1969 and fall 1969 water levels.

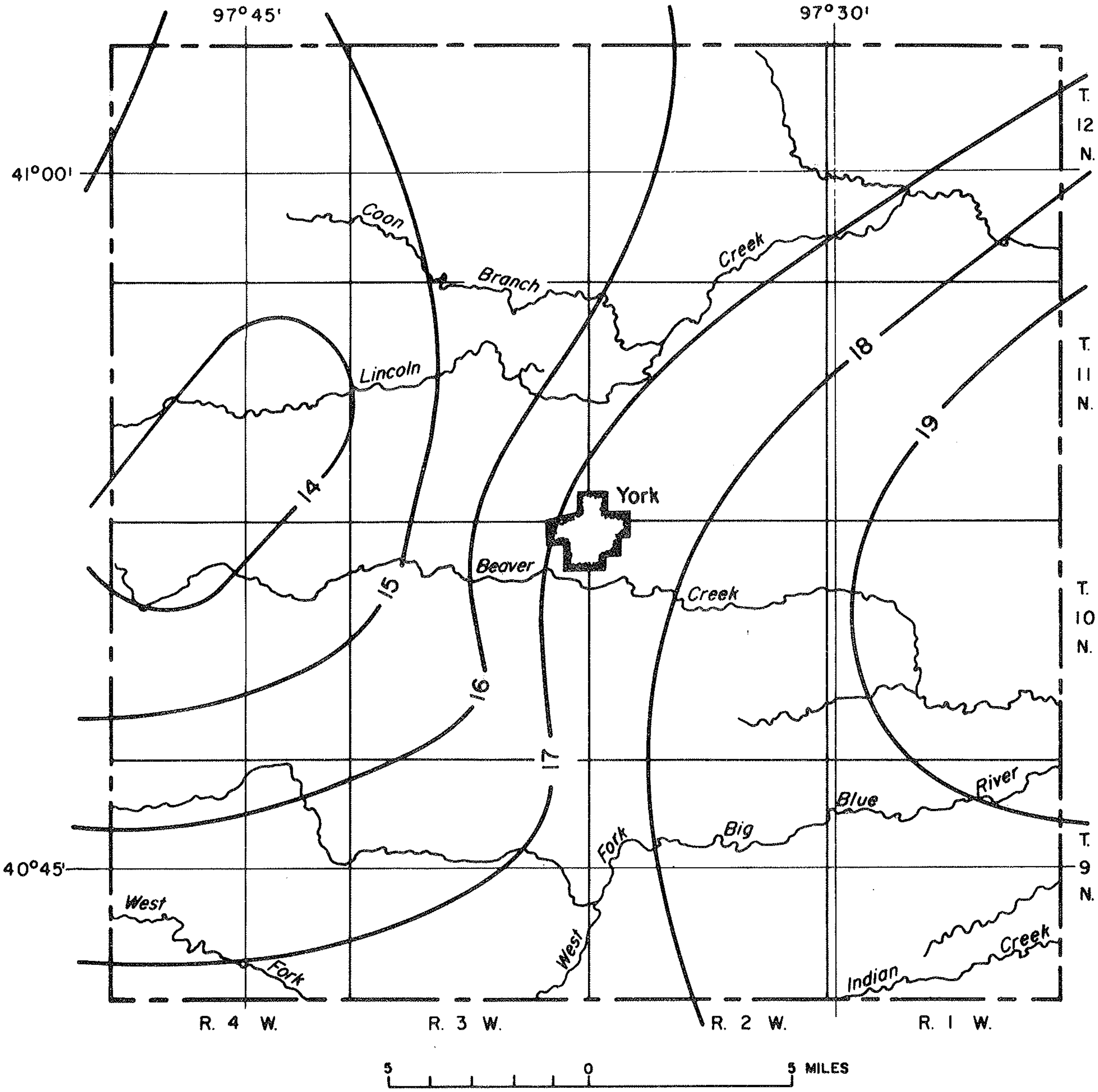


EXPLANATION

16

Line of equal accumulated rainfall, May-August 1969
Interval 1 inch

Figure 15. – Precipitation in Hamilton County, May through August 1969.



EXPLANATION

—16—

Line of equal accumulated rainfall, May-August 1969
Interval 1 inch

Figure 16.—Precipitation in York County, May through August 1969.

great in 1967 as those in 1966 even though precipitation during the May-August period in 1967 was about twice that of the same period in 1966. Furthermore, in 1969, when precipitation was well distributed through the late spring and summer months, the amount of groundwater used was considerably less than in 1967, when total growing-season precipitation was nearly the same but was less well distributed with respect to time. The difference in timeliness of precipitation in the two growing seasons is illustrated by the ratios of minimum to monthly rainfall; in 1967, the least monthly rainfall amount in the May-August period was about one-tenth that of the maximum monthly rainfall whereas in 1969 the least monthly rainfall was three-fifths that of the maximum.

Several other factors may affect the amount of water withdrawn. One, which might be reflected in areal differences in withdrawals, is the areal distribution of wells. For example, the density of well locations ranges from as few as 35 per township to as many as 135 per township (figs. 2 and 3) and although withdrawals per township may not be proportional to number of wells, it is almost certain that the combined withdrawals of a large number of wells would far exceed the combined withdrawals of a small number of wells. Also, both the yield rate of wells and the number of hours pumped differ considerably from well to well, as shown by data in tables 3 and 4.

It was thought reasonable that the depth of water applied to crops would tend to correlate with total May-through-August rainfall. However, the scattering of points when one is plotted against the other (fig. 17) affords no indication of a simple straight-line relation. Cumulative depths of application apparently are controlled by differences in a variety of factors, among which are the moisture-holding capacity of the soil, stage of crop growth when moisture application is needed, type of crop, number of acres irrigated from each well, and relation of well yield to number of acres irrigated. Values

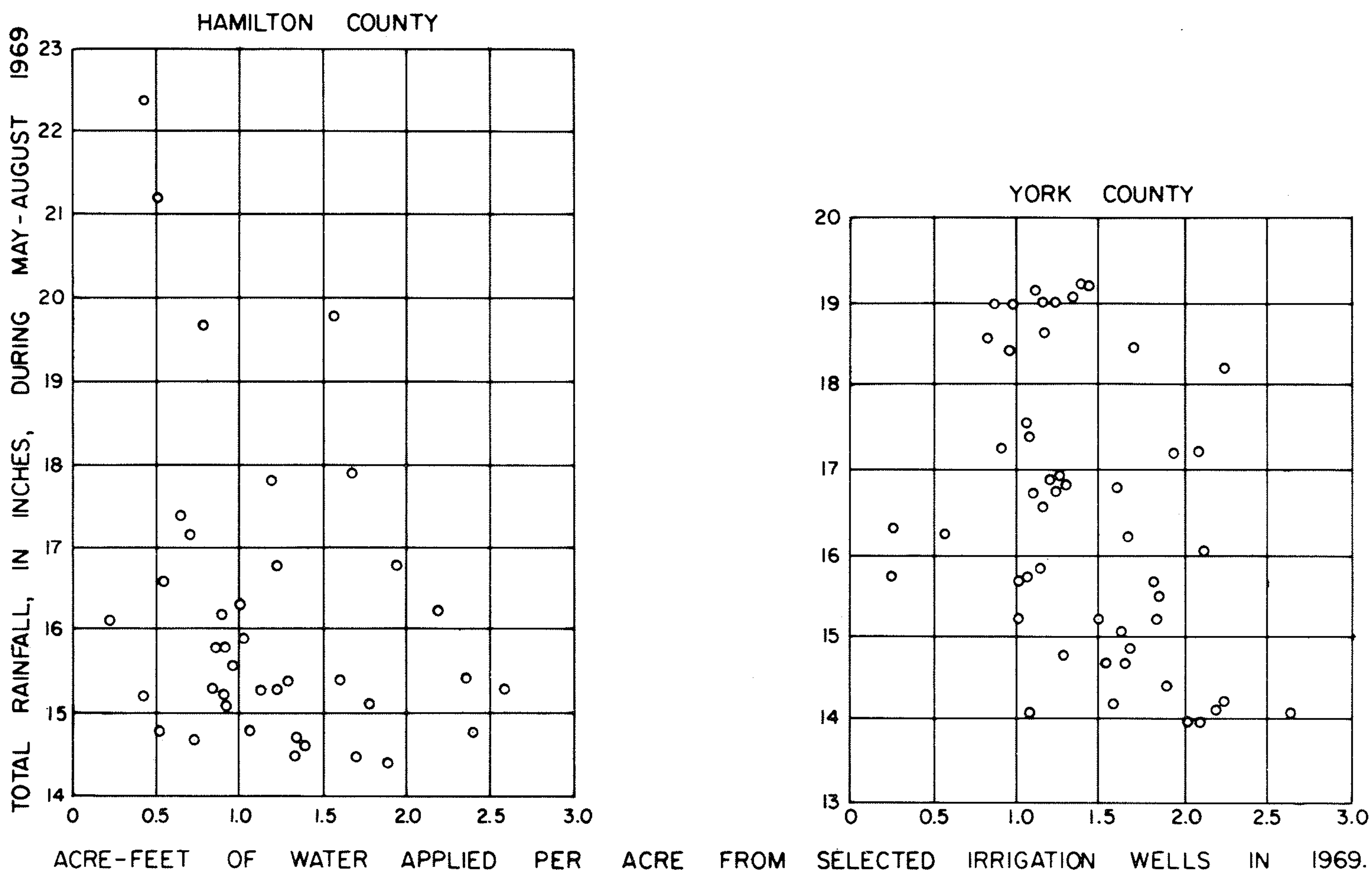


Figure 17. — Relation of May-through-August precipitation to depth of water applied for irrigation, 1969.

ranging from as little as 0.23 foot to as much as 3.18 feet were computed for depths of application during the 1969 irrigation season, and both the smaller and the larger values are scattered throughout the two-county area.

As may be seen from figure 18, depth of application (acre-feet per acre) varies widely with number of acres irrigated from each well. Generally, more water was applied from wells having either a larger than average yield or a smaller than average number of irrigated acres, and less water was applied from wells having either a smaller than average yield or a larger than average number of irrigated acres. Because wells differ so in yield, the operators of large-yield wells may tend to apply excess water to crops whereas operators of low-yield wells are likely to make more efficient use of the water. Determination of the optimal depth of water application for different crops would aid in development of conservation measures.

PUMPAGE IN 1969

The two methods of determining the amount of water pumped in 1969 give values that differ somewhat. The first method, based on number of irrigation wells and average pumpage (yield x hours pumped), gives about 188,000 acre-feet for Hamilton County and about 167,000 acre-feet for York County, as follows:

Total number of registered irrigation wells		Average pumpage from project wells (acre-feet)		Total pumpage (acre-feet)
		HAMILTON COUNTY		
1,744	x	108	=	188,352
		YORK COUNTY		
1,636	x	102	=	166,872

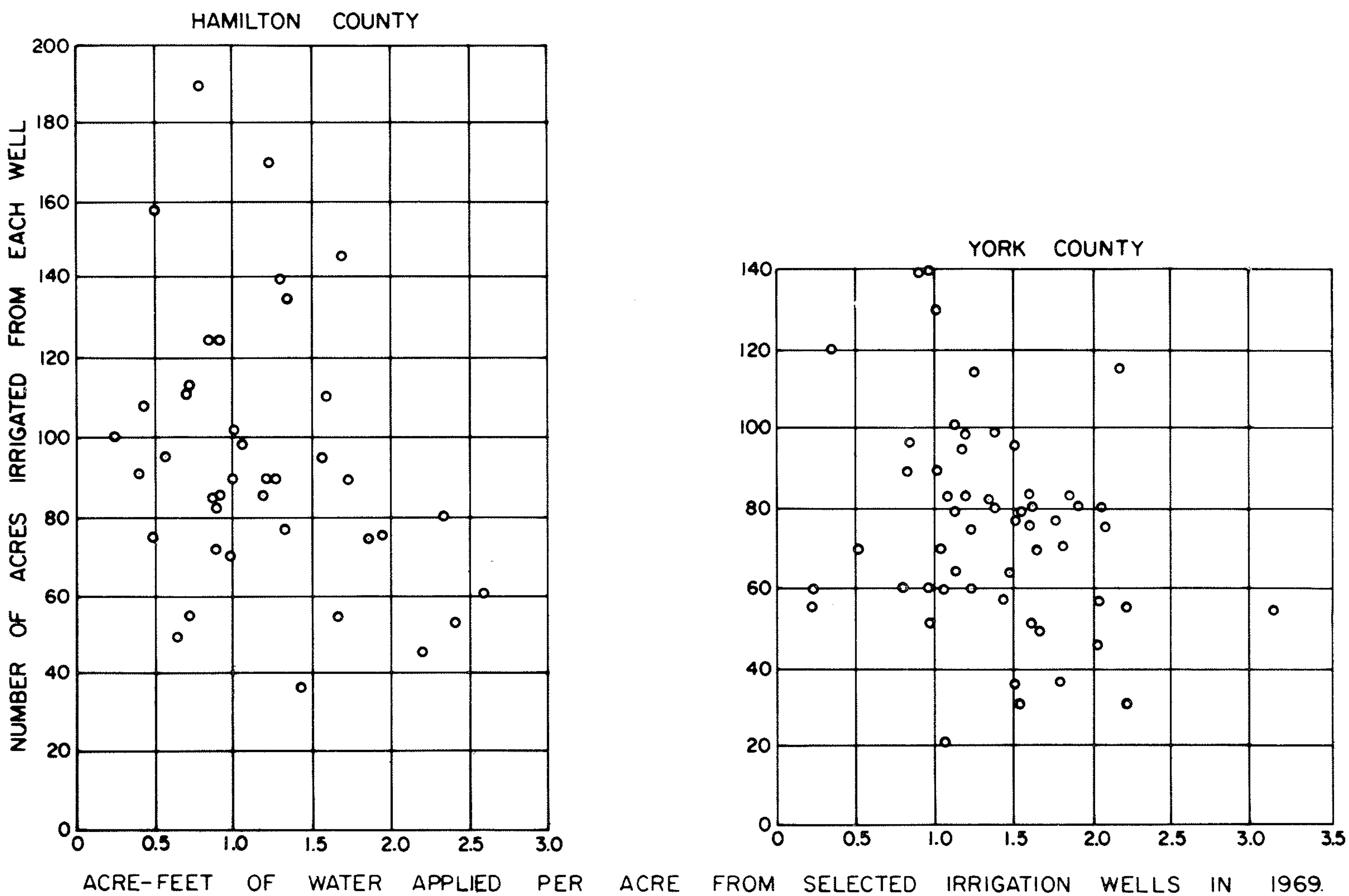


Figure 18. — Relation of irrigated acreages to depth of water applied for irrigation, 1969.

The second method, based on irrigated acreage (State-Federal Division of Agricultural Statistics, 1970) and depth of water applied, gives about 198,000 acre-feet for Hamilton County and 194,000 acre-feet for York County, as follows:

Total irrigated acres		Average depth of water applied from project wells (acre-feet per acre)		Total pumpage (acre-feet)
		HAMILTON COUNTY		
168,100	x	1.18	=	198,358
		YORK COUNTY		
149,500	x	1.30	=	194,350

If the project wells are typical of the irrigation wells and the reported number of irrigated acres in each county were correct, the values obtained by the two methods should be nearly the same. Therefore, from the rather large discrepancy between the two values for York County, it is concluded that the project wells in the county may be less typical than are those in Hamilton County, that the reported number of irrigated acres in York County is too large, or that irrigation practices in York County differ from those in Hamilton County. As the study in the two-county area proceeds, an attempt will be made to determine the best method for computing the amount of water pumped for irrigation. It is deduced from the hydrographs in figures 9 and 10 that the amount pumped in 1969 probably was nearly the same as that pumped in 1968 but was considerably less than the amounts pumped in the years 1963 through 1967, when the water-level trend was definitely downward.

If, in succeeding years, climatic conditions and annual withdrawals were to be about the same as in 1968 and 1969, the volume of groundwater in storage beneath the two-county area probably would not be seriously depleted for many years. However, there is no reason to assume that in some coming years climatic conditions will not result in considerably greater withdrawals than in 1968 and 1969. It is likely, therefore, that further net reductions in storage are likely to occur in those years, also that water levels again will trend downward. To extend the supply and slow the lowering of water levels, well operators should take care not to overirrigate and to minimize waste as much as practicable.

SUMMARY AND RECOMMENDATIONS

Groundwater withdrawals for irrigation before the spring of 1968 had reduced the supply in storage by about 585,000 acre-feet in Hamilton and about 430,000 acre-feet in York County. During the 2-year period spring 1968 to spring 1970, a slight net increase in storage occurred. However, the increase was not accompanied by a water-level rise in all wells, a slight further decline occurring in much of the area where the water level previously had been lowered the most. In view of the prospect for additional depletion of the supply, methods for extending the life of the resource should be explored and those that are feasible should be implemented.

It is recommended that measurement of water levels and hours of operation be continued in project wells and that the computer program be used for computation of annual changes in groundwater storage and of annual volumes of water pumped. To satisfy the need for better information on factors affecting pumpage, it also is recommended that a network of rain gages be installed and that measurements of soil moisture be made regularly at selected sites. An inventory of reuse pits and of the acreage irrigated with water from them would provide a sounder basis for computation of depth of water applied to crops.

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